

SCHOOL OF SCIENCE AND TECHNOLOGY EDUCATION
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA

11th HYBRID INTERNATIONAL CONFERENCE

THEME:

**STEAM EDUCATION
AND ARTIFICIAL INTELLIGENCE (AI):
BUILDING A SKILLED
AND INNOVATIVE
WORKFORCE**



CONFERENCE PROCEEDINGS

MONDAY 6TH TO FRIDAY 10TH OCTOBER, 2025

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

11th

**INTERNATIONAL CONFERENCE
OF SCHOOL OF SCIENCE AND TECHNOLOGY EDUCATION
(SSTE)**

ISBN: 979-978-52341-0-7

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SCIENCE AND TECHNOLOGY EDUCATION (SSTE)**

HYBRID CONFERENCE

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ACKNOWLEDGEMENTS

Local Organizing Committee of the 11th International Conference of School of Science and Technology Education (SSTE), Federal University of Technology, Minna, appreciates the Management of the University for the Unflinching Support given to the team which led to the success of this Conference. We also wish to express our profound gratitude for the assistance rendered by the University Management especially in disseminating information relating to this Conference using the University website, Campus News, and the University Search FM.

We are grateful to the Dean, School of Science and Technology Education (SSTE) for hosting this Conference despite the economic situation in the country. His encouragement, advice, and moral support gave the Local Organizing Committee the strength to complete this task and make the Conference successful.

We Sincerely thank the academic staff of the School and University Community for the essential roles played towards the success of the Conference. We thank the non-teaching staff for their roles which contributed to the success of this Conference.

Efforts of the Editorial Board are commendable for making sure that the Book of Proceedings is ready for use by the relevant stakeholders. We appreciate the efforts of the Keynote speaker, Lead Paper presenters, and all other participants for attending this Conference both physically and virtually despite their tight schedule.

We also commend the postgraduate students of the school for sparing their time to participate in all the events. Above all, we thank God Almighty for the strength given to the LOC members to discharge their enormous tasks.

PREFACE

The rapid integration of Artificial Intelligence (AI) in various industries has transformed the way we live and work, emphasizing the need for a skilled and innovative workforce. The convergence of Science, Technology, Engineering, Arts, and Mathematics (STEAM) education with AI has become a crucial factor in driving economic growth, innovation, and competitiveness.

This conference proceedings brings together experts, researchers, and practitioners to explore the intersection of STEAM education and AI, focusing on building a workforce equipped to thrive in an AI-driven world. The papers presented here cover a range of topics, including AI-powered learning tools, STEAM curriculum development, and the future of work in the age of AI.

Hence, the theme of this conference is apt and provides opportunities where experts brainstorm so that international communities can benefit from one another and also respond to emerging trends in *STEAM* Education and AI in order to build a skilled and innovative workforce. It is worth noting that, proper synergy of STEAM and AI would have a greater influence on the quality of manpower injected into the labour market which may determine the economic growth of any nation.

The theme and sub-themes of this conference, "**STEAM Education and Artificial Intelligence (AI): Building a skilled and innovative workforce**" are based on the prevailing circumstances in education sectors in developing nations. I am sure this conference has provided an avenue for researchers and educators to share their ideas on the 21st-century skills that can enhance quality education and self-reliance in underdeveloped and developing nations across the world. I hope the theme and sub-themes meet the needs of the stakeholders in education.

The sub-themes are:

- Artificial Intelligence, Teacher Education and Career Development
- Artificial Intelligence and Gender Issues in Education
- Language and Communication in the Era of Artificial Intelligence
- Transforming Library and Information Science Through Artificial Intelligence for Innovative Workforce
- Artificial Intelligence-Driven Entrepreneurship for Innovative Education
- Ethical Implications of Artificial Intelligence in TVET and STEAM Education
- I C T and Generative Artificial Intelligence in STEAM Education
- Agriculture and Artificial Intelligence for Food Security and Economic Sustainability
- Artificial Intelligence and Engineering Education for Skilled Workforce
- Artificial Intelligence-Driven Educational Technology for Innovative Workforce
- Inclusive Education in the Era of Artificial Intelligence
- Artificial Intelligence and Innovative Workforce in National Security

The Local Organizing Committee is thankful to the participants of 2025 conference for their contributions. God bless you all.

Prof. I. Y. Umar
LOC Chairman

**WELCOME ADDRESS BY THE VICE-CHANCELLOR, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, PROFESSOR FARUK ADAMU KUTA AT THE OPENING CEREMONY OF THE 11TH INTERNATIONAL CONFERENCE OF THE SCHOOL OF SCIENCE AND TECHNOLOGY EDUCATION, HELD AT SSTE BOARD ROOM, BOSSO CAMPUS, FUT MINNA.
6TH - 10TH October, 2025**

Distinguished colleagues, esteemed scholars, invited guests, ladies and gentlemen, it is with great delight and a profound sense of responsibility that, on behalf of the Governing Council, Management, Staff, and Students of the Federal University of Technology, Minna, I warmly welcome you all to the opening ceremony of the 11th International Conference of the School of Science and Technology Education. On behalf of the University community, I extend warm greetings to our participants from within Nigeria and across the globe who have joined us for this intellectually stimulating gathering. Your presence here is a testament to your commitment to advancing knowledge, innovation and collaboration in the critical fields of science, technology and education.

A warm welcome goes to all our distinguished speakers, especially our Keynote Speaker, Professor O. S. Olatunji, Dean, Faculty of Computing, Adekunle Ajasin University, Ondo State. We are equally honoured to have with us our Lead Paper Presenters: Professor Aede Hatib Bin Musta'amal, Faculty of Educational Sciences and Technology, University Teknologi Malaysia, Professor Jelili Adebayo Jimoh, Head of Department, Vocational and Technology Education, University of Lagos, Akoka, Lagos State, and, Professor Binyao Zheng, Bagwell College of Education, Kennesaw State University in the USA. We thank you sincerely for honouring our invitation and for bringing your wealth of expertise to enrich this conference.

The theme of this year's conference, ***"STEAM Education and Artificial Intelligence (AI): Building a Skilled and Innovative Workforce,"*** could not be more timely or relevant. In today's rapidly evolving global landscape, education must transcend traditional boundaries to equip learners with the competencies required for the 21st century. Science, Technology, Engineering, Arts and Mathematics (STEAM) provide a holistic framework that integrates creativity with technical expertise. Coupled with the transformative power of Artificial Intelligence, this framework promises to shape not only the future of education, but also the future of industry, governance, and everyday life.

Artificial Intelligence is no longer a distant prospect; it is already reshaping the way we work, learn and interact. From healthcare to agriculture, from business to the creative industries, AI is creating opportunities that demand new skills and fresh ways of thinking. For Nigeria and indeed Africa, the challenge before us is how to harness these opportunities to address our local needs, reduce inequalities and empower our youths with the skills necessary to thrive in an increasingly competitive world. This is why the discourse we begin today is of immense importance.

As a university of technology, FUT Minna remains committed to driving innovation, research, and entrepreneurship. We recognize that higher education institutions have a pivotal role in preparing a workforce that is not only technically competent but also adaptable, creative and ethically responsible. By embracing STEAM education and integrating Artificial Intelligence into our teaching and research, we are laying the foundation for a new generation of problem-solvers and innovators who can propel Nigeria and Africa into a future of sustainable growth and development.

I must commend the School of Science and Technology Education for its consistency in organizing this international conference, now in its 11th edition. Over the years, this conference has provided a platform for robust dialogue, collaboration and knowledge sharing among educators, researchers, and industry practitioners. This year's theme, in particular, challenges us to rethink our curricula, pedagogies and policies to align with global trends while remaining responsive to local realities.

Permit me to also acknowledge the efforts of the organizing committee whose dedication has ensured the success of this event. To our guests, I invite you to enjoy not only the academic engagements but also the warmth and hospitality of Minna and Niger State.

Once again, I warmly welcome you all to the 11th International Conference of the School of Science and Technology Education. May the deliberations here mark a turning point in our collective pursuit of excellence in education, innovation and nation-building. I wish you all a productive conference, an enjoyable stay in Minna and safe travels back to your various destinations when the event comes to a close.

Thank you and God bless you all.

**WELCOME ADDRESS BY
THE DEAN, PROFESSOR ROBERT O. OKWORI, SCHOOL OF SCIENCE AND
TECHNOLOGY EDUCATION, FEDERAL UNIVERSITY OF TECHNOLOGY,
MINNA, NIGER STATE, NIGERIA AT THE OPENING CEREMONY
OF THE 11TH INTERNATIONAL CONFERENCE OF THE
SCHOOL ON 8TH OCTOBER, 2025.**

The Vice-Chancellor Federal University of Technology, Minna
Deputy Vice-Chancellors (Academics and Administration)
Registrar
Bursar
Librarian
Keynote Speaker
Lead Paper Presenters
Deans, Heads of Departments,
Distinguished scholars,
Ladies and gentlemen

It is with great delight and a deep sense of responsibility that I, on behalf of the School of Science and Technology Education, Federal University of Technology, Minna, warmly welcome you all to the 11th International Conference of our School. This gathering continues our tradition of fostering academic excellence, advancing frontiers of knowledge, and providing platforms for dialogue on issues that shape the future of education and development, both within Nigeria and globally.

This year's theme, ***“STEAM Education and Artificial Intelligence (AI): Building a Skilled and Innovative Workforce”*** is timely and highly significant. Across the world, nations are aligning education with the demands of a rapidly changing technological landscape. For Nigeria, the integration of Science, Technology, Engineering, Arts, and Mathematics (STEAM) with the transformative power of Artificial Intelligence offers both immense opportunities and urgent responsibilities. AI is not only revolutionizing how we live and work but is also redefining the very fabric of education, how we teach, how students learn, and how knowledge is applied to solve societal challenges.

For our nation, this means preparing a workforce that is not only technically proficient but also innovative, adaptive, and creative. It calls for an education system that emphasizes problem-solving, critical thinking, and collaboration, thereby equipping Nigerian youths to compete in the global knowledge economy. More importantly, it calls for harnessing AI and STEAM education to address local challenges whether in healthcare, agriculture, energy, or national security while building sustainable pathways for development.

We are indeed privileged to have with us distinguished scholars and experts whose work embodies the spirit of this conference. Our Keynote Speaker, Prof. O. S. Olatunji, Dean of the Faculty of Computing, Adekunle Ajasin University, is a resourceful and innovative computer professional, researcher, and teacher. His expertise in Artificial Intelligence, Computational Intelligence, and Machine Learning applied across fields such as Oil and Gas, intrusion detection, biomedical prediction, and bioinformatics will no doubt provide us with invaluable insights into the revolutionary impact of AI on skills formation and professional growth. We are equally honored to welcome Prof. Jelili Adebayo Jimoh, Head of the Department of Vocational and Technology Education at the University of Lagos, whose contributions to vocational and technical education remain significant to Nigeria's quest for skills-based development.

From beyond our borders, we are delighted to host Prof. Aede Hatib Bin Musta'amal of Universiti Teknologi Malaysia, whose scholarship in technical and engineering education, particularly in creativity, innovation, and competency profiling in TVET, continues to shape global conversations on workforce readiness.

We are also privileged to have Prof. Binyao Zheng of Kennesaw State University, USA, a distinguished scholar in educational leadership, program evaluation and global citizenship education. His research on educational policy and student success brings a much-needed international perspective on how education systems can foster inclusivity and excellence.

At this juncture, I must sincerely acknowledge and commend the tireless efforts of the Chairperson and members of the Local Organizing Committee. Your dedication, meticulous planning, and unwavering commitment have made this 11th International Conference of the School of Science and Technology Education a reality. From the early stages of preparation to the seamless execution we are witnessing today, your teamwork and sacrifice have ensured that this gathering will be both intellectually rewarding and memorable. On behalf of the School, I say a heartfelt thank you.

Distinguished colleagues and guests, this conference is not only an academic exercise but also a call to action. As we deliberate, let us think critically about how we can adapt STEAM education and AI to meet Nigeria's developmental aspirations. Let us explore how academia, industry and government can collaborate to produce a skilled and innovative workforce that will drive sustainable growth.

On this note, I once again welcome you to the 11th International Conference of the School of Science and Technology Education. May our engagements here be intellectually stimulating, practically impactful, and historically significant.

Thank you, and welcome.

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KEYNOTE SPEAKER'S ADDRESS

STEAM EDUCATION AND ARTIFICIAL INTELLIGENCE: BUILDING A SKILLED AND INNOVATIVE WORKFORCE

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Abstract

The integration of STEAM (Science, Technology, Engineering, Arts, and Mathematics) education with Artificial Intelligence (AI) presents a transformative opportunity to prepare a workforce equipped for the demands of the 21st century. As industries increasingly adopt automation, big data, and digital technologies, education systems must go beyond technical training to cultivate creativity, adaptability, collaboration, and ethical judgment. STEAM provides a foundation for interdisciplinary learning, while AI enhances this framework by enabling personalization, data-driven insights, and inclusive access to knowledge. This paper explores how AI-enhanced STEAM education supports the development of hybrid skills needed for innovation across sectors such as healthcare, renewable energy, and digital media. It also examines challenges, including the digital divide, educator readiness, and ethical concerns, and highlights strategies for policy and industry collaboration. The study argues that embedding AI literacy and ethical responsibility within STEAM is essential for building a future-ready, skilled, and innovative workforce.

Keywords: *STEAM education; Artificial Intelligence; Workforce development; Digital literacy; Ethical AI; Innovation; Multidisciplinary learning; Sustainable development; Education policy; Future of work*

Introduction

The 21st century is defined by rapid technological disruptions, driven by advances in AI, robotics, and digital technologies (Schwab, 2016). The World Economic Forum projects that by 2030, more than one billion people will need to be reskilled due to automation and changing job requirements (World Economic Forum, 2020). This transformation underscores the urgency of rethinking education systems to prepare learners for roles that do not yet exist.

STEAM education, which is an approach that blends scientific inquiry, technological innovation, engineering design, artistic creativity, and mathematical reasoning, provides a holistic framework for equipping learners with interdisciplinary/multidisciplinary skills needed in this dynamic era (Yakman & Lee, 2012). When integrated with AI tools and applications, STEAM education has the potential to personalize learning, democratize access, and cultivate an agile and innovative workforce (Holmes et al., 2019).

The convergence of STEAM and AI is not only an educational opportunity but also a societal necessity. As digital transformation reshapes global economies, the demand for hybrid competencies, which include technical expertise combined with creativity, empathy, and ethical reasoning, has never been greater (Friedman, 2019). Unlike traditional subject-specific instruction,

STEAM nurtures problem-solving across disciplines, while AI enhances this learning by enabling personalized pathways, real-time feedback, and data-driven insights (Luckin et al., 2016). This partnership ensures that learners are not just adapting to technological changes but are positioned to lead innovation.

Furthermore, AI and STEAM together address critical global challenges. For instance, AI can accelerate medical research and diagnostics, while STEAM-trained professionals provide the creativity and design thinking needed for human-centered healthcare solutions. In climate science and renewable energy, AI models inform sustainable practices, while interdisciplinary STEAM education equips learners to interpret, design, and ethically apply such technologies (Chaudhry et al., 2022). These synergies highlight how AI-enhanced STEAM education contributes not only to workforce readiness but also to achieving broader Sustainable Development Goals (SDGs).

Finally, this integration raises essential cultural and ethical considerations. As AI continues to influence decision-making in classrooms, workplaces, and societies, it is vital that education cultivates ethical awareness alongside technical skills. Issues such as algorithmic bias, data privacy, and the equitable distribution of AI's benefits underscore the importance of embedding ethics at the core of AI-enhanced education (Crawford, 2021; UNESCO, 2023). By foregrounding ethics, educators and policymakers can build public trust and ensure that STEAM education powered by AI develops not only skilled workers but also responsible global citizens.

This paper situates STEAM and AI within global trends, recognizing that educational innovations must address not only technological readiness but also cultural contexts, ethical dilemmas, and international cooperation.

The Relevance of STEAM in Workforce Development

Traditional education models often prioritize narrow specialization, where students are trained deeply in a single discipline with limited exposure to other domains. While this has produced experts in specific areas, it is increasingly inadequate in today's interconnected and fast-changing world. The complex challenges of the 21st century, ranging from climate change and global health crises to digital transformation and ethical dilemmas in artificial intelligence, demand integrative approaches that cut across disciplines (Friedman, 2019).

STEAM education provides such an approach by blending scientific inquiry, technological fluency, engineering design, artistic creativity, and mathematical reasoning. Each element contributes uniquely to workforce readiness:

i. Science: Science cultivates inquiry, experimentation, and evidence-based reasoning. These skills are essential in a workforce that must evaluate data, generate new knowledge, and solve pressing problems. Scientific training enables professionals to analyze environmental impacts, conduct medical research, or test innovations with rigor and precision. In a world where misinformation spreads rapidly, a scientifically literate workforce also strengthens societies' ability to make sound decisions based on facts and evidence.

ii. Technology: Technology equips learners with digital literacy and fluency in tools that drive the modern economy. Beyond technical know-how, it fosters adaptability to new systems such as

artificial intelligence, blockchain, and virtual reality. Technology is not just about using devices but about understanding how they work and how they can be leveraged to solve problems. For example, AI-powered diagnostic systems in healthcare require workers who can operate, interpret, and improve these technologies while ensuring ethical application.

iii. Engineering: Engineering emphasizes structured problem-solving and systems thinking. It teaches individuals to break down complex challenges into smaller, manageable tasks and to design solutions that are practical, scalable, and efficient. In the workforce, this translates into skills for creating resilient infrastructure, designing sustainable products, and improving industrial processes. Engineering also instills resilience, as iterative design processes encourage learning from mistakes and adapting to new constraints.

iv. Arts: The arts add a human-centered dimension to STEAM education, fostering creativity, empathy, and design thinking. In today's workforce, these skills ensure that innovation is not only functional but also culturally relevant, ethical, and accessible. Artistic perspectives enhance storytelling, product design, and communication, which are skills that are crucial in industries ranging from digital media to user experience (UX) design. By integrating the arts, STEAM produces graduates who can connect technology with human needs, making innovations more impactful.

v. Mathematics: Mathematics provides the foundation for analytical reasoning, quantitative analysis, and logical problem-solving. It underpins the growing demand for data literacy, which is the ability to interpret, manipulate, and extract insights from large datasets. In fields such as finance, logistics, and AI development, mathematical skills are indispensable for modeling scenarios, predicting outcomes, and making evidence-based decisions. Beyond technical utility, mathematics fosters abstract thinking that sharpens creativity and innovation. When combined, these five pillars produce a holistic skillset that is critical for today's workforce. Modern employers are not only looking for technical specialists but also for adaptable, multidisciplinary thinkers who can bridge knowledge gaps, work collaboratively, and innovate responsibly. STEAM education, therefore, is not simply an academic framework but a strategic investment in future-ready human capital.

Employers increasingly seek professionals who can navigate complexity, work across disciplines, and create innovative solutions (Friedman, 2019). STEAM fosters these attributes by combining technical competence with creative problem-solving and human-centered design.

Recent surveys of employers highlight skills such as collaboration, adaptability, and innovation as being equally important as technical knowledge. STEAM uniquely cultivates these skills by encouraging project-based learning, cross-disciplinary collaboration, and exposure to real-world problems.

Artificial Intelligence as a Catalyst for Education Transformation

Artificial Intelligence (AI) is no longer a futuristic concept, it has become a central feature of contemporary society and is increasingly integrated into education systems worldwide (Luckin et al., 2016; Holmes et al., 2019). Within the context of STEAM education, AI functions in two major ways: first, as a discipline in its own right that students must understand in order to thrive in AI-

driven economies; and second, as a transformative tool that redefines how teaching, learning, and assessment are conducted. By bridging these two roles, AI is reshaping education to prepare a skilled, innovative, and inclusive workforce. In this respect, the following important concepts are examined:

i. Personalizing Learning: Traditional education often adopts a “one-size-fits-all” approach, which struggles to accommodate learners with different strengths, paces, and needs. AI has revolutionized this through adaptive learning systems and intelligent tutoring technologies. Platforms such as Carnegie Learning, Century Tech, and Squirrel AI use algorithms to monitor student progress in real time, adjusting lessons to fit individual learning trajectories. For example, a student struggling with algebra can receive more practice and scaffolded explanations, while a more advanced student is introduced to higher-level concepts. This personalization not only improves learning outcomes but also fosters confidence and motivation. Research by Luckin et al. (2016) highlights that such adaptive systems are particularly effective in mathematics and science, areas where learners often face significant barriers.

ii. Enhancing Engagement: Engagement is a major determinant of student success, especially in STEAM education where practical experimentation is essential. AI-powered simulations, gamified platforms, and virtual laboratories allow students to explore concepts in interactive ways that traditional classrooms cannot always provide. For example, Labster’s virtual labs enable students to conduct science experiments that might otherwise be too dangerous, costly, or resource intensive. Similarly, augmented reality (AR) and AI-driven simulations bring engineering and design challenges to life, allowing learners to manipulate 3D models and test prototypes virtually. This not only strengthens conceptual understanding but also sparks curiosity and creativity.

iii. Supporting Teachers: Teachers remain at the heart of education, yet they face mounting challenges, including large class sizes, administrative workloads, and growing expectations for data-driven instruction. AI can serve as a powerful support system. Automated grading tools reduce the time teachers spend marking assignments, freeing them to focus on higher-value activities such as mentoring and personalized instruction. Predictive analytics systems also provide teachers with insights into student performance, identifying at-risk learners early and suggesting targeted interventions. For instance, some school districts in the United States are piloting AI platforms that analyze attendance, homework completion, and test performance to generate real-time “student risk profiles” (Holmes et al., 2019). This empowers teachers to take proactive steps to support student success.

iv. Expanding Access and Equity: AI-powered platforms are increasingly being used to overcome geographic, socioeconomic, and linguistic barriers to education. Intelligent learning systems can reach students in rural and underserved communities where access to qualified teachers and physical resources is limited. For example, initiatives in sub-Saharan Africa and South Asia are using AI-driven mobile applications to deliver quality educational content to learners who may not have access to traditional schools (Ayeni et al., 2024). AI-based translation tools, such as Google’s Neural Machine Translation system, also allow students from different linguistic backgrounds to collaborate in real time, breaking down language barriers and fostering global cooperation in STEAM projects.

v. Promoting Inclusivity: AI also plays a pivotal role in creating more inclusive learning environments (UNESCO, 2021). Natural language processing (NLP) tools support learners with reading difficulties, while speech recognition technologies enable students with visual or motor impairments to interact more fully with digital content. Tools like Microsoft's Immersive Reader or Google's speech-to-text services exemplify how AI can empower students with disabilities to engage meaningfully in STEAM activities. Beyond accessibility, AI can also reduce bias in assessment by standardizing evaluation methods, ensuring fairness across diverse groups of learners.

vi. AI as a Learning Discipline: Beyond serving as an educational tool, AI itself has become a crucial field of study within STEAM. Understanding AI's principles, capabilities, and ethical implications is essential for students entering an AI-driven workforce. Courses in AI and machine learning are being introduced in secondary schools and universities globally, preparing learners not just to use AI, but to innovate with it. Importantly, AI literacy also encompasses ethical awareness, such as understanding algorithmic bias, data privacy, and the societal implications of automation (Chan, 2023). Integrating AI as a core subject within STEAM curricula ensures that graduates are not only consumers of AI technologies but also critical creators and responsible digital citizens.

The Transformative Potential of AI in STEAM

Collectively these applications highlight AI's transformative potential within education. AI fosters personalization, inclusivity, efficiency, and global connectivity while equipping learners with the skills needed to thrive in the digital economy. By embedding AI into STEAM education, nations can cultivate a workforce that is not only technically proficient but also innovative, ethical, and prepared to solve complex global challenges.

Building a Skilled and Innovative Workforce through STEAM + AI

The future workforce will not be defined by purely technical expertise alone, but by the ability to integrate science, technology, engineering, arts, and mathematics (STEAM) with the transformative power of artificial intelligence (AI). Emerging roles increasingly demand hybrid skill sets that combine technical knowledge with creativity, adaptability, and ethical responsibility (Yan et al., 2023). By embedding AI into STEAM education, we create a workforce capable of thriving in complex and dynamic global environments.

AI-driven STEAM education supports this transformation by:

i. Digital and AI Literacy: Learners must be equipped not only to use AI tools, but also to understand how these technologies function, their limitations, and their societal impact (Luckin et al., 2016). This literacy includes programming basics, data analysis, and algorithmic thinking, as well as critical evaluation of AI-generated outputs. For instance, students trained in AI literacy are better positioned to adapt as industries automate processes, implement predictive analytics, and introduce generative design systems.

ii. Creative Innovation: Integrating the arts within STEAM empowers learners to approach challenges with imagination and divergent thinking. When combined with AI, this creativity

amplifies possibilities in fields such as architecture, music composition, and digital storytelling. For example, designers can use AI to prototype sustainable buildings more efficiently, while artists can experiment with new forms of interactive media that merge human emotion with machine intelligence.

iii. Critical Thinking and Ethics: The responsible use of AI requires strong ethical foundations. Students must be able to question data sources, recognize bias, and understand the broader societal implications of algorithmic decision-making (Crawford, 2021; Winfield & Jirotko, 2018). Embedding ethics into AI education fosters accountability and builds public trust. In healthcare, for example, professionals who understand both the benefits and risks of AI diagnostics will be better prepared to make patient-centered decisions.

iv. Collaboration Skills: Work in the AI era is increasingly global and interdisciplinary. Students trained in digital collaboration platforms, AI-assisted project management tools, and cross-cultural communication will be able to contribute to distributed teams seamlessly. A global workforce connected through AI-enabled virtual environments can collectively tackle issues like climate change or humanitarian crises by pooling diverse expertise in real time.

V. Entrepreneurial Mindsets: AI enhances entrepreneurial capacity by enabling rapid prototyping, predictive trend analysis, and opportunity recognition. Students who develop entrepreneurial skills alongside AI fluency can create ventures that are both innovative and sustainable (Chaudhry et al., 2022). For example, renewable energy startups already use AI to optimize grid efficiency, while small businesses leverage AI-driven marketing tools to reach global audiences at low cost.

vi. Application in Key Industries: The integration of STEAM and AI is already visible across sectors. In healthcare, AI-trained clinicians use machine learning to improve diagnostics while drawing on empathy and communication skills to enhance patient care. In renewable energy, engineers and data scientists collaborate with designers to develop efficient, human-centered systems that address climate challenges. In digital media and entertainment, creators use AI to generate immersive content that merges storytelling, design, and data-driven personalization.

By fostering a skilled and innovative workforce, STEAM + AI education ensures that learners are not just job-ready, but future-ready, capable of adapting to new technologies, leading ethical innovations, and shaping industries that prioritize both human and societal well-being.

Challenges and Ethical Considerations

While integrating AI into STEAM education has the potential to unlock innovation, equity, and creativity, it also presents systemic challenges. These must be addressed deliberately to ensure that AI-enhanced learning benefits all students, not just a privileged few.

The key challenges include:

- **Digital Divide:** Many schools and communities still lack access to the digital infrastructure required for AI-enabled education. Unequal access to high-speed internet, devices, and AI tools risk deepening global and local inequities (UNESCO, 2021).

- **Educator Readiness:** Teachers are often underprepared to integrate AI concepts into their teaching. Professional development and ongoing support are necessary to help educators navigate both the technical and ethical dimensions of AI in education (Holmes et al., 2019).
- **Ethical Concerns:** AI introduces risks related to bias, transparency, surveillance, and data privacy. Without appropriate safeguards, AI can unintentionally reinforce inequalities, infringe on student rights, or create distrust in educational systems (Crawford, 2021; UNESCO, 2023).
- **Curriculum Adaptation:** Education systems are often slow to evolve, while AI technologies advance rapidly. Static curricula risk leaving students underprepared for the jobs and ethical dilemmas of the future (Yan et al., 2023).

Policy Recommendations and Best Practices

To turn these challenges into opportunities, a **multi-stakeholder strategy** is essential. Below are actionable steps in this regard:

1. **Bridging the Digital Divide:**
 - a. **Infrastructure Investment:** Governments should prioritize funding for broadband internet, cloud-based learning platforms, and affordable devices, especially in underserved regions.
 - b. **Public-Private Partnerships:** Collaboration with technology companies can accelerate equitable access by providing subsidized software and hardware for schools.
 - c. **Community Hubs:** Schools and libraries can serve as digital access centers, ensuring students without home internet can still engage with AI-driven education.
2. **Strengthening Educator Readiness:**
 - a. **Professional Development Programs:** Establish continuous training for teachers that combines technical AI knowledge with STEAM pedagogy and ethics.
 - b. **AI Teaching Assistants:** Deploy AI-powered tools that support teachers in lesson planning, grading, and personalized learning, allowing educators to focus on higher-order skills.
 - c. **Peer Learning Networks:** Encourage communities of practice where educators share resources, strategies, and challenges related to AI integration.
3. **Embedding Ethics and Responsible AI Use:**
 - a. **Ethics by Design:** Ensure all AI tools used in education are transparent, explainable, and respectful of student privacy.
 - b. **Curriculum Integration:** Introduce age-appropriate discussions on fairness, accountability, bias, and sustainability in AI, beginning at the primary level and deepening through higher education.
 - c. **Oversight Mechanisms:** Establish independent boards or committees to review AI adoption in education for ethical compliance and equity.

4. **Adapting and Future-Proofing Curricula:**

- a. **Interdisciplinary Frameworks:** Update curricula to integrate AI across subjects, e.g., using machine learning in science labs, exploring generative AI in arts, or applying data analysis in social studies.
- b. **Flexible Modular Learning:** Design curricula in modules that can be updated regularly to reflect technological advances.
- c. **Industry Collaboration:** Partner with industry leaders to align curricula with real-world skills, ensuring students are equipped for emerging job markets.

The Central Role of Ethics

At the heart of these reforms lies **ethics in AI education**. Training students to question fairness, transparency, and accountability ensures they become not just competent professionals, but also thoughtful leaders and responsible citizens. Embedding ethical inquiry into STEAM + AI education helps future innovators prioritize inclusivity, human rights, and sustainability as much as technological advancement.

Looking Ahead

The integration of AI into STEAM education is not merely a technological shift, it is a societal one. Governments, schools, industry, and civil society must work together to:

- Guarantee equitable access to AI learning opportunities,
- Empower educators with the tools and training they need,
- Safeguard ethics and privacy, and
- Continuously evolve curricula to prepare learners for future challenges.

If approached strategically, these challenges can be transformed into steppingstones toward a more inclusive, ethical, and innovative educational ecosystem.

6. Policy and Industry Implications

For STEAM + AI education to truly transform the workforce, systemic change is required at the intersection of **policy, education, and industry innovation**. The challenge is not just equipping individuals with new skills but also creating enabling ecosystems that sustain lifelong learning, ethical practice, and inclusive growth.

1. National AI-in-Education Frameworks

Governments must establish clear national strategies that prioritize AI literacy across all levels of education (UNESCO, 2021). Strategies include:

- a. **Early Introduction:** AI concepts can be integrated into primary education through age-appropriate coding, digital citizenship, and creative AI applications in art and storytelling.
- b. **Secondary and Tertiary Education:** Curricula should progress toward advanced topics such as machine learning, data science, and human-AI collaboration.
- c. **Teacher Training & Standards:** A framework must also include certification programs, guidelines for AI-enabled teaching, and funding for teacher professional development.
- d. **Global Coordination:** Countries should align with international efforts (e.g., OECD AI principles, UNESCO guidelines) to ensure comparability and mobility of skills.

2. Public-Private Partnerships (PPPs)

Collaboration between governments, academia, and industry is essential to bridge the gap between education and labor markets. Industry and academia must co-create innovation hubs, internships, and research (Gao et al., 2023)

- a. **Innovation Hubs & Labs:** Establish regional centers of excellence where students, researchers, and startups experiment with AI in real-world STEAM applications (e.g., healthcare, renewable energy, creative industries).
- b. **Work-Integrated Learning:** Expand opportunities for apprenticeships, AI-driven internships, and industry-funded research projects that immerse students in practical contexts.
- c. **Shared Resources:** Partnerships can also reduce costs by pooling access to data, cloud computing, and AI software for educational institutions.

3. Lifelong Learning Platforms

The rapid pace of technological change demands that workers continuously update their skills. AI-powered platforms can make this process adaptive, personalized, and inclusive. AI-powered adaptive systems can support reskilling and modular learning (Ayeni et al., 2024). The following is very instructive in this respect.

- a. **Adaptive Learning Systems:** Platforms can tailor content based on learners' skills, progress, and career goals.
- b. **Micro-Credentials & Modular Learning:** Industry-recognized certifications in areas like data ethics, creative AI, or green technologies can empower workers to upskill quickly.
- c. **Inclusive Access:** Governments and companies should subsidize or sponsor lifelong learning initiatives to ensure disadvantaged groups are not excluded.

4. Ethical AI Standards

Embedding ethics into policy and industry practice is not optional, it is foundational to building public trust in AI-enabled education (UNESCO, 2023).

- a. **Global Frameworks:** Adoption of shared standards on fairness, transparency, accountability, and inclusivity ensures cross-border compatibility and ethical consistency.
- b. **Data Governance:** Robust regulations are required for handling student data, protecting privacy, and ensuring that AI-driven assessments do not reinforce systemic biases.
- c. **Ethical Certification:** Industry-led initiatives can create certification schemes for “responsible AI tools” in education, similar to sustainability certifications in other sectors.

Policy-Industry Synergy: Toward a Future-Ready Workforce

The integration of AI into STEAM education requires **alignment across multiple levels of society**:

- **Governments** must provide direction through policies, funding, and frameworks.
- **Industry** must supply tools, expertise, and real-world applications that ground learning in practice.
- **Academia** must adapt curricula, drive research, and train educators.
- **Civil society** must hold stakeholders accountable for inclusiveness, ethics, and transparency.

When these sectors collaborate, the result is not only a more skilled and innovative workforce, but also a better prepared society to **navigate the ethical, economic, and cultural transformations** of the AI era.

Conclusion

The convergence of STEAM education and Artificial Intelligence represents not just an educational innovation, but a societal transformation. By combining technical fluency with creativity, critical thinking, and ethical awareness, AI-enhanced STEAM learning empowers individuals to thrive in an era defined by complexity and change. The next generation of workers will not merely adapt to technological disruption, they will be prepared to shape, guide, and humanize it.

Realizing this vision requires collective action; government must implement robust AI-in-education frameworks, industries must forge partnerships that align learning with real-world needs, and educators must be supported as facilitators of innovation and ethical inquiry. At the same time, global cooperation is essential to ensure equity: without addressing the digital divide and embedding fairness at the core of AI systems, the benefits of this transformation risk being unevenly distributed.

Ultimately, AI-enhanced STEAM education should be recognized as a strategic foundation for sustainable development, not a peripheral experiment. It is a pathway toward more resilient economies, inclusive societies, and responsible innovation. By investing today in the integration of STEAM and AI, we are investing in a future workforce that is not only skilled and innovative, but also ethical, adaptable, and globally connected.

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LEAD PAPER I

From Perception to Practice: TVET Students' Acceptance and Use of AI Tools

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Abstract

Artificial intelligence (AI) is rapidly transforming education, yet its adoption in Technical and Vocational Education and Training (TVET) depends heavily on students' acceptance and trust. This study therefore examined Malaysian TVET students' acceptance and behavioural intention to use AI tools through the Technology Acceptance Model (TAM). A survey was conducted with 151 students from two TVET institutions. The questionnaire measured four constructs—Perceived Usefulness (PU), Perceived Ease of Use (PEOU), Acceptance (ACC), and Behavioural Intention (BI). Likert-scale items adapted from previous studies were used, and data were processed with SPSS 27 through descriptive, correlational, and regression analyses. Results supported TAM's relevance in vocational education: PEOU had a significant effect on PU, while both variables contributed to ACC. Notably, ACC emerged as the strongest determinant of BI, underscoring its pivotal role in students' readiness to adopt AI. Descriptive analyses revealed overall favourable views, yet concerns about long-term use persisted. The study emphasizes that cultivating positive attitudes and building digital trust are crucial for integrating AI effectively in TVET. Future work should investigate cross-cultural variations, educator preparedness, ethical considerations, and the enduring influence of AI adoption on employability.

Key Words: *Artificial Intelligence in Education; TVET; Student Attitudes; Technology Adoption; Behavioral Intention*

Introduction

The fast-growing development of artificial intelligence (AI) is reshaping diverse areas of human activity, with applications now present across nearly all sectors. In higher education, AI has likewise become a focal point of research (Minn, 2022; Cantú-Ortiz et al., 2020). For instance, Pham *et al.* (2023) investigated the use of tools such as ChatGPT in engineering courses at a Southeast Asian university and reported encouraging effects on student learning. AI use in Technical and Vocational Education and Training (TVET) has been acknowledged since 2015 in connection with the United Nations' Sustainable Development Goals (SDGs) (Qadir *et al.*, 2023; Ryan *et al.*, 2019). Studies also indicate that AI-driven personalized learning supports skill acquisition and better alignment between educational outcomes and labor market demands (Berigel *et al.*, 2025).

In Malaysia, AI is increasingly integrated to assist both educators and learners. The country's higher education sector is rapidly digitizing, guided by the Malaysia Education Blueprint 2015–2025, which promotes the adoption of emerging technologies (Aun *et al.*, 2022). Comparable

trends are seen internationally; for example, in Nigeria and elsewhere, TVET teachers are expected to employ AI tools in lesson design, instruction, and evaluation (Tourni et al., 2023).

Among various AI applications, ChatGPT is distinctive for its conversational capability, ability to deliver tailored feedback, and support for diverse learning styles, positioning it as a valuable tool for personalized education. Hettiarachchilage and Haldolaarachchige (2023) also showed that ChatGPT enhances interaction and teamwork in online discussions and group projects, particularly within educational settings.

In the TVET context, AI shows considerable promise for improving learning experiences. Learners using ChatGPT reported gains in understanding and engagement, while research highlights the need for flexible curricula. For instance, a decision-making study in the end-of-life automobile sector stressed that AI adoption, vocational training, and industry partnerships are vital for employability (Zary & Zary, 2025). Overall, integrating AI in TVET is anticipated to enhance both skill development and student participation.

Nonetheless, several challenges persist. Doubts about the accuracy and credibility of AI outputs shape students' views of its usefulness. Although AI tools are increasingly employed for instruction and assessment, many learners remain skeptical of the dependability of AI-generated feedback. This skepticism is intensified by the opaque nature of AI algorithms, which can erode trust and limit students' willingness to rely on such systems for essential academic tasks (Al-Emran, Abu-Hijleh, & Alsewari, 2024; Bond et al., 2020, as cited in Mat Yusoff et al., 2025).

At the societal level, AI is reshaping the job market, with far-reaching implications for TVET. AI not only enhances learning experiences and skill development but also equips students to meet future workforce demands (Rosyadi et al., 2023). UNESCO IIEP (2025) noted that as the labor market evolves rapidly, the TVET system is striving to keep pace. According to the World Economic Forum (2023), by 2027 approximately 69 million new jobs may be created globally, while 83 million jobs could be displaced, resulting in a net loss of 14 million jobs (roughly 2% of current employment). AI is a key driver of both job creation and job displacement, intensifying the need for reskilling and upskilling in AI-related competencies.

In this context, mastering and applying AI tools has become an essential component of skills development in TVET. If students are willing to use AI, the focus must shift to how these tools are applied to ensure meaningful learning. Conversely, if students lack the willingness to engage with AI, its potential benefits in teaching and learning will not be fully realized. As a result, strengthening students' intention to adopt AI is not only a crucial prerequisite for effective integration of AI tools but also a pathway to enabling students actively incorporate AI into their learning processes, acquire the core skills required in the future labor market, and ultimately strengthen their career competitiveness.

Therefore, this study aims to examine the applicability of the Technology Acceptance Model (TAM) in the context of TVET, with a particular focus on exploring the influence paths of Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) on students' Acceptance of AI Tools (ACC) and their Behavioral Intention (BI). There are three research questions that this article seeks to answer which include (i) how does Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) influence Acceptance of AI tools (ACC), (ii) to what extent does students'

Acceptance of AI tools (ACC) further influence their Behavioural Intention (BI)?, (iii) what strategies can be proposed to strengthen TVET students' acceptance and behavioral intention toward AI tools based on the findings?

Methodology

The questionnaire design of this study is guided by the Technology Acceptance Model (TAM; Davis, 1989). It has been widely applied in education to investigate the acceptance of emerging technologies such as e-learning platforms, artificial intelligence, and digital learning tools, particularly in relation to perceived benefits and usage behaviour (Puiu, 2024).

This study focused on the core TAM pathway: the influence of Perceived Ease of Use (PEOU) and Perceived Usefulness (PU) on Acceptance of AI Tools (ACC), with ACC subsequently influencing Behavioral Intention (BI). The instrument comprised four constructs: PU, PEOU, ACC, and BI, measured using multiple items adapted from prior studies (Baharin et al., 2024; Amdan et al., 2025). These items were adjusted to align with the TVET learning context (e.g., classroom learning, practical training) and AI tool usage scenarios (e.g., ChatGPT, Deepseek, and AI-driven learning platforms). All items were measured on a five-point Likert scale (1 = "strongly disagree," to 5 = "strongly agree") to quantitatively capture the direction and intensity of students' perceptions and attitudes.

The survey was study employed online using Google Forms as the tool for questionnaire distribution and data collection. It was designed and distributed online, to ensure convenience, anonymity while minimizing geographical constraints. Bilingual processing (Malay and English) was undertaken prior to distribution to improve clarity. The participants were students from two Malaysia TVET institution in Malaysia, and the data were collected over three weeks. A total of 151 responses were obtained. As all items were mandatory, no missing values were recorded, and all responses were retained after screening abnormal patterns.

The data analysis was conducted using SPSS 27.0. Preliminary checks for missing values, outliers, and normality were conducted. Cronbach's α was then used to assess the reliability of each construct, followed by the descriptive statistics where the mean, standard deviation, skewness, and kurtosis were calculated. Correlation analysis examined the relationships among Perceived Usefulness (PU), Perceived Ease of Use (PEOU), Acceptance of AI Tools (ACC), and Behavioral Intention (BI). Finally, multiple regression analysis tested the effect paths between the variables.

Reliability analysis demonstrated excellent internal consistency across all four constructs as shown in Table 1. Specifically, Cronbach's α values were .92 for PU, .92 for PEOU, .93 for ACC, and .90 for BI, all exceeding the .70 threshold recommended by Nunnally & Bernstein, (1994). Therefore, the instrument can be considered highly reliable for measuring participants' perceptions and intentions toward AI tools.

Table 1 Reliability analysis of constructs (N = 151)

Construct	Items	Cronbach's α
PU	4	.92
PEOU	4	.92
ACC	4	.93
BI	4	.90
Overall	16	.96

Note. Cronbach's $\alpha > .70$ indicates acceptable internal consistency (Nunnally & Bernstein, 1994).

Data Findings and Discussions

A total of 151 students participated in the survey. As presented in Table 2, the sample comprised 113 males (74.8%) and 38 females (25.2%). Most respondents were enrolled in Mechanical Engineering (108, 71.5%), with smaller proportions from Civil Engineering (24, 15.9%) and Electrical Engineering (19, 12.6%). In terms of academic level, 61 students were in their first year (40.4%), 37 were in their second year (24.5%), and 53 were in their third year (35.1%). In terms of institutional distribution, 87 students were from TVET Institution A (57.6%) and 64 from TVET Institution B (42.4%).

Table 2 Demographic Characteristics of Participants (N = 151)

Variable	Category	<i>n</i>	%
Gender	Female	38	25.2
	Male	113	74.8
Major	Civil Engineering	24	15.9
	Electrical Engineering	19	12.6
	Mechanical Engineering	108	71.5
Year of Study	Year 1	61	40.4
	Year 2	37	24.5
	Year 3	53	35.1
TVET Institution	A	87	57.6
	B	64	42.3

From the statistical analysis, the findings in Table 3 reveal that PU scores ranged from 1.25 to 5.00, with a mean of 4.01 (SD = 0.80), suggesting that most respondents generally perceived AI tools as highly valuable. Similarly, PEOU scores ranged from 1.00 to 5.00, with a mean of 3.94 (SD = 0.81), indicating that students generally considered AI tools to be relatively easy to use. In the case of ACC, scores ranged from 1.00 to 5.00, with a mean of 3.95 (SD = 0.83), reflecting positive acceptance attitude. By contrast, BI scores ranged from 1.00 to 5.00, with a mean of 3.77 (SD = 0.83), which, although slightly lower than the other constructs, still represented a moderately high level. Taken together, these results suggest that students not only valued and accepted AI tools, but also demonstrated a relatively clear intention to continue using them in the future.

Table 3 Descriptive statistics of core constructs ($N = 151$)

Variable	M	SD	Min	Max
PU	4.01	0.80	1.25	5.00
PEOU	3.94	0.81	1.00	5.00
ACC	3.95	0.83	1.00	5.00
BI	3.77	0.83	1.00	5.00

Note. M = mean, SD = standard deviation.

The Pearson correlation analysis, which presented in Table 4 showed that all variables were significantly and positively related ($p < .01$). Specifically, PU was strongly correlated with PEOU ($r = .72$, $p < .001$), ACC ($r = .74$, $p < .001$), and BI ($r = .69$, $p < .001$), suggesting that perceptions of usefulness enhance ease-of-use judgments, acceptance, and continued use. Likewise, PEOU also correlated positively with ACC ($r = .74$, $p < .001$) and BI ($r = .72$, $p < .001$), confirming that greater ease of use leads to more positive attitudes and stronger intentions. Notably, the strongest correlation was between ACC and BI ($r = .83$, $p < .001$), showing that acceptance is the key driver of students' behavioral intention to use AI. These significant correlations provided a strong foundation for the subsequent regression analysis to further examine the hypothesized TAM pathways.

Table 4 Correlation matrix of core constructs ($N = 151$)

Variable	1	2	3	4
1. PU	—			
2. PEOU	.72**	—		
3. ACC	.74**	.74**	—	
4. BI	.69**	.72**	.83**	—

Note. ** $p < .01$ (two-tailed).

In this study, Multivariate Regression analyses were conducted to examine the hypothesized paths among the core TAM variables, as presented in Table 5. To begin with, in the model with PU as the dependent variable, PEOU emerged as a significant predictor PU ($\beta = .72$, $p < .001$), explaining 52% of the variance $R^2 = .52$, $F(1,149) = 162.57$, $p < .001$. Next, in the model with ACC as the dependent variable, both PU ($\beta = .44$, $p < .001$) and PEOU ($\beta = .42$, $p < .001$) were significant predictors, accounting for 64% of variance ACC ($R^2 = .64$, $F(2,148) = 130.02$, $p < .001$). Finally, in the model where BI was the dependent variable, ACC ($\beta = .71$, $p < .001$) and PU ($\beta = .17$, $p = .013$) significantly predicted BI, explaining 70% of the variance ($R^2 = .70$, $F(2,148) = 175.86$, $p < .001$). Taken together, these results strongly support the TAM framework and clearly demonstrate the transmission pathway of PEOU $\rightarrow$ PU $\rightarrow$ ACC $\rightarrow$ BI.

Table 5 Multiple regression analysis predicting PU, ACC, and BI (N = 151)

Outcome (DV)	Predictor (IV)	B	SE	β	t	p	R ²
PU	PEOU	0.72	0.06	.72	12.75	<.001	.52
ACC	PU	0.45	0.07	.44	6.12	<.001	.64
	PEOU	0.43	0.07	.42	5.89	<.001	
BI	ACC	0.71	0.07	.71	10.56	<.001	.70
	PU	0.18	0.07	.17	2.52	.013	
Outcome (DV)	Predictor (IV)	B	SE	β	t	p	R ²

Note. *p < .05. **p < .01. ***p < .001.

The findings of this study validate the applicability of the Technology Acceptance Model (TAM) in the vocational education context and highlight the central role of acceptance attitudes in influencing students' behavioral intentions to continue using AI tools. As shown in Table 2, the sample is primarily composed of first-year male Mechanical Engineering students from two TVET institutions. Furthermore, the descriptive statistics in Table 3, indicated that PU (M = 4.01), PEOU (M = 3.94), and ACC (M = 3.95) were all at relatively high levels, while BI was slightly lower (M = 3.77). Taken together the results suggest that respondents generally held positive attitudes toward AI tools and demonstrated strong intentions to use them (Gnambs et al., 2025). In addition, Correlation analysis in Table 4, revealed significant positive relationships among all variables ($p < .01$), with the strongest association observed between ACC and BI ($r = .83$). The regression analysis provides strong evidence for the applicability of the Technology Acceptance Model (TAM) in the context of TVET students. First, Perceived Ease of Use (PEOU) significantly predicted Perceived Usefulness (PU) ($\beta = .72$, $p < .001$), indicating that when students perceive AI tools as easier to use, they are more likely to view them as useful. This finding aligns with Davis's (1989) foundational TAM assumption that ease of use is an important antecedent of perceived usefulness.

Second, PU and PEOU jointly and significantly predicted Acceptance (ACC) ($\beta = .44$, $\beta = .42$, both $p < .001$), suggesting that students' evaluations of both the usefulness and the ease of use of AI tools play a critical role in fostering positive attitudes and acceptance. This implies that enhancing either the usability of tool design or the relevance of tools in learning contexts can effectively strengthen students' acceptance. Similarly, Teo (2011) demonstrated that teachers' attitudes toward educational technologies are significantly influenced by both PU and PEOU, while Baharin et al. (2024) found that in a Malaysian TVET sample, ease of use and usefulness perceptions were key determinants of learners' positive attitudes.

Finally, PU ($\beta = .17$, $p = .013$) and ACC ($\beta = .71$, $p < .001$) significantly predicted Behavioral Intention (BI). Although perceived usefulness retained a significant effect, the much stronger pathway was from acceptance to behavioral intention, underscoring the mediating role of students' affective attitudes in driving their actual intention to use AI tools. Consistently, previous studies confirmed that in AI educational applications, positive attitudes and acceptance are often stronger predictors of sustained usage intention than cognitive beliefs alone (Anghel et al., 2025; Zou & Huang, 2023). Collectively, these results provide strong support for the TAM framework and underscore the pivotal role of ACC in predicting behavioral intention.

Conclusions.

This study validates the relevance of the Technology Acceptance Model (TAM) in TVET, showing that Perceived Ease of Use (PEOU) shapes Perceived Usefulness (PU), and together they influence Acceptance (ACC). Notably, ACC proved to be the strongest predictor of Behavioral Intention (BI), indicating that cultivating favorable attitudes is more decisive than usability alone in sustaining students' willingness to adopt AI tools.

Descriptive results showed that although students viewed AI tools as useful, easy to use, and generally acceptable, concerns about sustained adoption remained. Key issues included doubts over output reliability, particularly critical in engineering where small errors can have serious impacts, along with unease about opaque systems and the possibility that extended reliance could weaken independent thinking and learning. Practical barriers, such as unstable internet access and occasional inaccuracies in AI-generated information, further discouraged continued use.

These findings highlight acceptance as the key link between perceptions and behavioral intention. For TVET educators and policymakers, successful AI adoption entails embedding tools in authentic vocational contexts, fostering digital trust through training and practical cases, and aligning applications with industry-relevant competencies.

For future research, it is advisable to expand the sample size to cover more diverse TVET institutions, explore research angles related to cross-culture and long-term dynamics, and investigate such factors as teachers' readiness, ethical concerns, and the enduring impacts of AI adoption on employability. Through these efforts, researchers can gain deeper understanding of how to utilize AI in a responsible and efficient way, thereby strengthening students' skill building and enhancing their competitiveness in the job market.

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LEAD PAPER II

STRATEGIES FOR HARNESSING THE POTENTIAL OF ARTIFICIAL INTELLIGENCE APPLICATIONS IN TECHNOLOGY EDUCATION

Being a Lead Paper Presented at the 11TH School of Science and Technology Education International Conference of The Federal University of Technology, Minna between 6th to 10th October, 2025 at School of Science and Technology Education Board Room.

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Introduction

It is a great pleasure and privilege to address this assembly of Erudite Scholars, Vice Chancellor and Eminent Personalities to present a Lead Paper. I thank the organizers of this 11th School of Science and Technology Education (SSTE) International Conference of the Federal University of Technology, Minna for their thoughtfulness in selecting such a relevant and timely theme and for considering me worthy of this honour to address you. I fully intend to utilize the opportunity to share my thoughts on a number of contemporary issues on Artificial Intelligence (AI) that I hope will stimulate further discussions, policy interventions and actions for an overall meaningful and positive impact on AI applications in Technology Education in Nigeria.

This year's conference theme, 'STEAM Education and Artificial Intelligence: Building a Skilled and Innovative Workforce,' is particularly relevant given the revolutionary shift in the global educational landscape, largely influenced by the increasing use of Artificial Intelligence (AI). In Technology Education, where practical skills and hands-on experience are paramount, AI offers unprecedented opportunities to enhance learning outcomes, customize instruction, and prepare students for the ever-evolving demands of the 21st-Century workforce.

This Theme is also an important area of discourse in Science, Technology Engineering, Art and Mathematics (STEAM) because from personalized learning platforms to AI-driven tutoring systems, artificial intelligence is rapidly transforming how we teach and learn. Technology education specifically encompasses a wide range of disciplines, including Automechanics, Building construction, Metalwork, woodwork, and electrical/Electronic technology. Traditional methods, though foundational, are often constrained by factors such as lack of resources, teacher limitations, and rigid curricula. AI has emerged as a transformative tool that can address these challenges by offering personalized, adaptive, and immersive learning experiences.

The word 'Artificial intelligence' is often defined from the perspective of human intelligence. In psychology, human intelligence is the general mental ability involved in calculating, reasoning, perceiving relationships and analogies, learning quickly, storing and retrieving information, using language fluently, classifying, generalizing, and adjusting to new situation (Lagasse, 2012). According to Rainer et al., (2016) AI is designed to create intelligent systems with computer programs or machines which are capable of intelligent behaviours including learning, reasoning, problem- solving, perception, and creating. Artificial intelligence (AI), according to (Russell & Norvig (2021) is the ability of a machine to perform tasks that typically require human intelligence.

AI is also called ‘machine intelligence’. It is an aspect of computer science where machines are programmed with the ability to perform intelligent tasks that are usually undertaken by humans (Ali, et al. 2024; Dwivedil et al. 2023). AI is therefore a universal field that is relevant to all intellectual tasks. Educational activities around the world have been significantly exposed to technological advancements in recent times by the intervention of recent development in Artificial Intelligence. AI is transforming industries and requiring a future-ready workforce. Technology education students are at the forefront, prepared to inherit this evolving digital world through technology.

Despite the government's emphasis on technology education, the traditional methods of learning have not kept pace with the country's commitment to technological advancement. Hence, the need for integrating AI into our educational system. The integration of technology, particularly AI, into the education curriculum in Nigeria has become a crucial focus in contemporary education policy and discourse. However, the implementation of technology education programs in Nigerian institutions has faced significant challenges, including insufficient skilled manpower, and inadequate infrastructure. The acceptance, adoption and application of AI tools can help fill these gaps. In technology education, AI presents unique opportunities to enhance teaching and learning experiences, automate administrative tasks, and prepare students for a rapidly evolving workforce. This paper explores applications of AI in technology education with emphasis on strategies for harnessing the potential of AI in technology education.

Applications of AI in Technology Education

Application of AI into technology enhances not just theoretical understanding but also the development of practical skills. According to Vootukuri & Jyothi (2024) students’ learning experience is enhanced when AI application is designed to empower teachers and facilitate the management of complex institutional operations to augment the delivery of education. Artificial intelligence (AI) tools are increasingly integrated into teaching and learning to enhance personalization, efficiency, and accessibility. AI in education includes intelligent tutoring systems, conversational agents, adaptive learning environments, analytics dashboards, and automated assessment tools (U.S. Department of Education, 2023). The following are key application areas:

Personalized Learning

Personalized learning refers to educational activities that cater to individual student needs and learning styles. It is a means by which content of instruction is delivered based on each student’s ability, weaknesses, learning difficulties, and learning styles allowing students to learn concepts at their own pace. For example, AI such as ChatGPT can be used to provide students in technology education individualized-specific feedback, guidance, and support. Teachers can help to create a more individual-adaptive and engaging process that is tailored to the needs of each student (Dwivedi *et al.*, 2023)

Virtual Reality Laboratories and Simulations

Virtual reality and online testing open a few doors for spatial visualization research and measurement. Virtual reality is the name of the interactive computer technology that attempts to create a completely convincing illusion of being immersed in an artificial world which exists only inside a computer. Virtual reality is a superior environment for spatial skills enhancement specifically because the interface preserves visio-spatial characteristics of the simulated world. AI

powered virtual reality creates immersive environments for training in automotive repair, welding, and machining for technology education students. AI provides a virtual reality environment through adaptive learning environments, which allows the development of practical sessions and exercises without the limitations of physical resources. AI-powered simulations create safe, cost-effective environments for hands-on practice. For instance, Technology education students and teachers can experiment with electrical circuits, CAD/CAM designs, or programming robots without physical components.

Intelligent Tutoring Systems (ITS)

Intelligent tutoring system carries the full burden of instruction as it explains information or concepts to students. Embedded questions and review activities are used to assess the ability of the students in acquiring the contents. Intelligent tutoring system is an AI application that helps to provide adaptive learning. It is used to facilitate instruction where the level of difficulty of instruction increases as students improve and at the same time, it tracks students' learning styles. Intelligent Tutoring Systems (ITS) are computer programs that track student knowledge and progress, providing personalized, step-by-step assistance. Unlike fixed digital resources, ITS can respond right away to student mistakes or misunderstandings. Several widely used ITS illustrate the application of AI in real classrooms. For instance, Cognitive Tutor (developed at Carnegie Mellon University) adapts algebra and geometry instruction to each learner's problem-solving path, offering hints and customized exercises. AutoTutor employs natural language processing to engage students in conversational dialogues, asking probing questions and providing feedback on subjects such as reading comprehension, physics, and computer literacy (Graesser, McNamara, & VanLehn, 2018). AI-powered intelligent tutoring systems in technology education provide simulations for students to learn task performance in virtual environments, such as machine operation. ITS is also used where students struggle to accomplish tasks to provide scaffolding such as step-by-step guidance, hints, or explanations to help them complete the task, gradually withdrawing support as the student gains proficiency. In doing so, ITS tracks a student's progress, identifying mastered skills and concepts, as well as areas needing more practice. The ITS then selects appropriate practice problems or tasks to reinforce learning and build confidence (Wang et al. 2003; Fitria, 2021).

AI-Powered Adaptive Learning Systems

Adaptive learning systems tailor instruction dynamically based on students' prior knowledge, progress, and performance. By analyzing learner data in real time, these systems adjust content difficulty, sequencing, and type of instructional support. Adaptive platforms can accelerate mastery learning and reduce time-to-completion compared with fixed-sequence instruction (Pane, Steiner, Baird, & Hamilton, 2015). Prominent examples include ALEKS, Knewton Alta, and DreamBox Learning, which adapts mathematics instruction for K–8 learners based on hundreds of interaction variables per lesson. At the higher education level, McGraw-Hill's LearnSmart and Pearson's MyLab incorporate adaptive quizzes and feedback loops. However, alignment with curricula and teacher readiness remain crucial for effective use (Holmes *et al.*, 2022).

Automated Assessment and Feedback

AI-automated assessment and grading uses artificial intelligence to automatically score and evaluate student work, offering efficient, consistent, and immediate feedback, saving teacher's time and reducing workload. In Technology education, AI automated assessment and grading

system can be used for assessment of students. The system analyzes various assessment formats, which may include essays and programming assignments, by using Natural Language Processing (NLP) and machine learning algorithms to compare responses against predefined rubrics. These systems significantly reduce turnaround time, enabling rapid feedback loops that support student self-regulation (Lu, Huang, & Chen, 2018; Kasneci et al., 2023).

AI-Powered Content Creation

AI-powered content authoring tools help educators generate quizzes, simulations, and adaptive exercises tailored to learner profiles (Chen, Xie, & Hwang, 2020). For instance, Quizlet's Q-Chat produces adaptive practice questions, while Knewton Alta creates problem sets aligned to learner progress. Generative AI models such as ChatGPT are also used for draft lesson planning and case development. In STEM education, virtual labs powered by AI offer scalable alternatives to physical experiments. Platforms like Labster allow students to conduct complex experiments virtually (De Jong, Linn, & Zacharia, 2013), while PhET Interactive Simulations incorporate adaptive hints. Although effective, such labs may lack the tactile experience of traditional labs, necessitating blended approaches. AI content creation generates dynamic content such as 3D models, simulations, and instructional videos, facilitating the teaching of complex engineering and technological concepts.

Predictive Analytics and Learning Analytics

This is AI application which analyzes students' data to predict outcomes and recommend interventions and helps educators identify at-risk students and adapt teaching methods. Specifically, learning analytics tools gather and study data about how students interact with their courses, like how often they log in, how much time they spend on tasks, and how they do assignments. Dashboards show these patterns in a clear way, helping teachers' spot students who might need extra help. When teachers use dashboards, they can manage courses better, give more personalized support, and help students take charge of their own learning. Examples include Moodle Analytics and Canvas Analytics, which track engagement levels and predict performance. The Open Learner Model (OLM) provides students with visualizations of their progress, encouraging self-monitoring (Bull & Kay, 2016). Similarly, Course Signals uses predictive modeling to flag students at risk of failing, while Civitas Learning combines institutional data with machine learning to inform retention strategies.

Strategies for harnessing the potential of AI in Technology Education

The potential of AI can be harnessed to create more engaging, effective, and equitable learning experiences for all students and teachers in technology education by implementing the following strategies:

Curriculum Integration Strategies

- **AI Literacy across the Curriculum:** AI should not be confined to computer science courses. AI concepts should be integrated into other subjects in technology education; for instance, AI simulations could model complex systems in metalwork, woodwork, electrical/electronics, automobile engineering, and building construction. The pedagogical rationale behind this approach is that it will help students develop a holistic understanding of AI and its impact on different fields.

- **Project-Based Learning with AI:** Engage students in hands-on projects that involve designing, building, or using AI-powered tools, such as creating a chatbot to answer questions about a specific topic or developing an AI-powered image recognition system for identifying machine or building parts. This approach promotes active learning, problem-solving skills, and collaboration among students and teachers

Teaching and Learning Strategies

- **Blended learning:** Blended learning integrates various strategies, combining face-to-face interaction with ICT. By incorporating AI, such as ChatGPT, with traditional methods like lectures, group discussions, and collaborative learning, technology education teachers can foster student interaction with peers and instructors, creating a social and engaging learning environment
- **Personalized Learning with AI-Powered Platforms:** Personalized learning is instructional method specially made for a particular student or group of students that cater to individual student needs and learning styles. Personalized learning enables teachers to create a tailored, engaging process that meets each student's needs. It involves using AI-driven platforms that adapt to individual student needs and learning styles. Adaptive learning platforms adjust content difficulty based on performance, while AI-powered tutoring systems provide personalized feedback and guidance. This strategy differentiates instruction, maximizes student engagement, and promotes mastery learning
- **AI-Assisted Assessment and Feedback:** Use AI to automate grading, provide instant feedback, and identify areas for additional student support. This can be achieved using AI-powered tools for automatic assignment grading and feedback, as well as chatbots to answer questions and clarify concepts. This frees up teacher time for individualized instruction, provides timely feedback, and supports student self-assessment.
- **Ethical Discussions and Critical Thinking:** this involves Facilitating discussions about the ethical implications of AI and encourage students to think critically about its impact on society. For instance, involving students should discuss the potential for bias in AI algorithms. Debating the ethical considerations of autonomous vehicles. Analyzing the impact of AI on employment and the future of work. This will Develops students' ethical reasoning skills, promotes responsible AI development and use, and prepares them to be informed citizens in an AI-driven world.

Teachers Development and Support Strategies

- **Professional Development on AI and Education:** Technology teachers should stay informed about AI developments through constant training and support on integrating AI into their teaching activities. This can be achieved through workshops and conferences, online courses and resources on AI pedagogy, and mentoring programs pairing experienced AI educators with newcomers. This will build teacher confidence, enhance AI knowledge, and equip them with effective AI tool skills

- **Collaboration and Knowledge Sharing:** To foster innovation, promote peer learning, and accelerate effective AI strategy adoption, technology education institutions should create teacher collaboration opportunities, sharing AI best practices through online forums, professional learning communities focused on AI integration, and teacher-led workshops on AI innovations.
- **Access to Resources and Support:** Technology teachers should have the resources and support needed to implement AI, including funding for AI tools and software, technical support for troubleshooting AI issues, and curriculum materials that incorporate AI. This will help to reduce barriers to AI adoption, ensures equitable access to technology, and empowers teachers to experiment with new approaches.

Addressing Challenges and Ensuring Equity

- **Data Privacy and Security Policies:** To builds trust, safeguards student information, and ensures compliance with privacy regulations; institutions should Implement strict data privacy and security policies to protect student data when using AI-powered tools.
- **Equitable Access to Technology and Connectivity:** To promote fairness, reduce discrimination, and ensure equitable outcomes, all students should have the technology and internet connectivity needed for AI-powered learning, reducing the digital divide, ensuring equal access to educational opportunities, and promoting social justice

Conclusion and Recommendations

Technology education, a component of vocational education, is a skills-based program designed to equip individuals with the practical skills, attitude, understanding, and knowledge necessary for vocational expertise and employment. Today's educational practices are undergoing an AI-driven shift. Therefore, technology education should adopt AI to prepare students for the labor market. AI offers immense potential to transform technology education by enhancing skill acquisition, improving learner engagement, and ensuring inclusivity. To fully harness this potential, a strategic, inclusive, and sustainable approach must be adopted, ensuring future technologists are active innovators and creators, not passive consumers of AI. Thus, successful AI adoption requires investment in infrastructure and teacher training, collaboration between educational institutions and tech developers, and ethical considerations in data use and AI deployment. It is therefore recommended that:

1. Technology education institutions should develop framework for adoption of AI.
2. Technology teachers should update their knowledge and skills on the usage of AI.
3. Administrators of Technology education institutions should constantly organize training on applications of AI for technology teachers.

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DEVELOPMENT AND EVALUATION OF VIRTUAL KAP SIMULATION TO ENHANCE BIOLOGY STUDENTS' LEARNING OUTCOMES IN SECONDARY SCHOOLS IN MINNA METROPOLIS, NIGER STATE, NIGERIA

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Abstract

This study developed and evaluated Virtual KAP, a simulation platform designed to enhance biology learning outcomes among senior secondary school students in Minna Metropolis, Niger State, Nigeria. The research adopted a quasi-experimental pretest–posttest design involving 83 SSII students purposively selected from two schools, with one group taught reproduction using Virtual KAP and the other through conventional demonstration. Data were collected using the Biology Reproduction Performance Test (BRPT). Findings revealed that students taught with Virtual KAP achieved significantly higher mean gain scores (30.84) compared to those taught without it (12.45). Similarly, retention gains were greater in the experimental group (16.64) than in the control (1.35), indicating that the simulation promoted deeper understanding and long-term recall of biological concepts. Gender-based analysis showed no significant difference in retention, suggesting that the tool is equally effective for male and female learners. These results affirm the constructivist view that interactive, technology-based learning fosters engagement and meaningful knowledge construction. The study concludes that Virtual KAP significantly enhances students' academic achievement and retention in biology, thereby addressing challenges associated with inadequate laboratory facilities and traditional teaching limitations. The study recommends the integration of simulation tools into classroom practice and curriculum design to improve learning outcomes and sustain interest in biology across genders.

Keywords: Virtual KAP, Simulation, Biology, Students and Senior Secondary School

Introduction

In the 21st century, the integration of technology into education has revolutionized the way students learn and interact with scientific concepts. Biology, as a core science subject in Nigeria's secondary school curriculum, demands hands-on experimentation and visualization to foster deep understanding (Okon and Yusuf, 2022). However, many schools in Minna Metropolis, Niger State, face challenges such as inadequate laboratory facilities, limited access to equipment, and overcrowded classrooms, which hinder effective science instruction. To bridge this gap, virtual simulations have emerged as innovative tools that replicate laboratory experiences digitally (Audu, 2018). The development of Virtual KAP, a customized biology simulation platform, aims to provide students with interactive, immersive learning experiences that mimic real-life biological experiments. By leveraging digital technology, Virtual KAP seeks to enhance students' conceptual understanding, engagement, and academic performance in biology (Adebayo, 2021).

Biology is a branch of science that deals with the study of living organisms. Biology is primarily concerned with the nature of organisms and their relationship to each other and to their

environment. Biology as a subject enable one understand major biological processes (Physiological) example digestion, respiration, circulation, excretion and gaseous exchange. Through Biology organisms tend appreciate the effect of these biological processes and the larger environment as a whole. Biology like other science subjects is a practical oriented discipline which seeks to develop in a learner, scientific inquiry and problem-solving skills. The general goals of Biology Education are to equip the learner with the basic knowledge, skills and attitude that will enable one to lead an independent and useful life (Samikwo, 2013).

In today's rapidly evolving educational landscape, student learning outcomes in biology are increasingly influenced by the integration of technology into classroom instruction. Traditional methods of teaching biology often limited to textbook explanations and sporadic practical sessions have proven insufficient in helping students grasp complex scientific concepts and retain information effectively (Sasikala and Siriwan, 2016). Many students struggle to connect theoretical knowledge with real-world biological processes, leading to poor academic performance and diminished interest in the subject. The use of computer-based simulations, such as virtual laboratories, offers a transformative solution by creating immersive, interactive environments where students can visualize and manipulate biological systems. These simulations replicate real-life experiments, allowing learners to engage with content actively rather than passively. As a result, students develop stronger conceptual understanding, improved critical thinking skills, and greater confidence in applying scientific principles. In regions like Minna Metropolis, where access to physical lab resources is limited, virtual tools like Virtual KAP can significantly enhance learning outcomes by bridging the gap between theory and practice, fostering deeper engagement, and promoting long-term retention of biological knowledge (Solikhin *et al*, 2019).

Statement of the Problem

Many secondary schools in the Minna Metropolis lack the proper infrastructure to support consistent, laboratory-based learning in biology. This has contributed to a number of issues, including low student retention, poor academic outcomes, and a general lack of interest in science-related careers. Traditional teaching methods often rely on rote memorization and theoretical instruction, which don't meet students' need for hands-on experience. This absence of engaging and accessible lab experiences creates a learning gap that makes it difficult for students to understand complex biological processes (Michael, 2017).

Reports from the West African Examination Council (WAEC) in 2017 and 2018 have highlighted that student are often unable to make logical inferences from experimental results or connect the structure of a specimen to its function. These findings suggest a decrease in student achievement in biology, which may be due to a lack of interest in the concepts being taught and poor retention of what they learn. One major contributing factor could be the lack of or poor use of instructional materials during the teaching and learning process. This decline in performance is a concern for students, teachers, parents, and other stakeholders, as it could lead to a shortage of professionals in fields like medicine and education (Sunday, 2015). There is a pressing need to find alternative teaching strategies that can simulate lab conditions and improve learning outcomes. The core issue is the limited use of virtual simulations like Virtual KAP, and the lack of empirical evidence to show how effective they are in improving biology education in the region.

Objectives of the Study

The primary aim of this study is to develop and evaluate the effectiveness of Virtual KAP, a biology simulation platform, in improving learning outcomes among secondary school students in Minna Metropolis, Niger State. Specifically, the study seeks to:

1. investigate the academic achievement score of students taught reproduction using virtual KAP and those without virtual KAP.
2. determine the retention rate of reproduction among students exposed to Virtual KAP and those without virtual KAP.
3. identify gender-based differences in learning outcomes resulting from the use of the virtual KAP.

Research Questions

1. What is the mean academic achievement score of students taught reproduction using virtual KAP and those without virtual KAP?
2. what is the retention rate of biological concepts among students exposed to Virtual KAP and those without virtual KAP?
3. what is the difference in the retention scores of male and female students taught reproduction using virtual KAP and those taught without virtual KAP?

Research Hypotheses

HO₁: There is no significant difference in the mean academic achievement scores of students taught reproduction using virtual KAP and those taught without using virtual KAP

HO₂: There is no significant difference in the mean retention scores of Biology students taught reproduction using virtual KAP and those without virtual KAP

HO₃: There is no significant difference in the retention scores of male and female students taught reproduction using virtual lab

Materials and Method

The research design adopted for the study is the quasi-experimental design involving Pretest and Posttest and Posttest using experimental and control group. The instruments for the study include Biology Reproduction Performance Test (BRPT) which was developed by the researcher. The Pretest was administered using RPT instruments to Experimental group and control group before treatment to establish equivalence in prior knowledge of the two groups. The treatment for the study in experimental group was virtual KAP while the control group received demonstration method. This was followed by Posttest after three weeks of teaching to determine the students' academic performance in students taught reproduction concepts. The population of the study comprises all Senior Secondary School students SSII within Minna metropolis with a population of five thousand one hundred and seven (5107). Purposive sampling technique was used to select two secondary schools and assigned to experimental group (computer simulation group) and control group (Demonstration teaching methods) respectively. Finally, stratified simple random sampling technique was used to select 83 SSII students. The experimental group had 42 (23 male – 19 female) students and control 41 (21 male – 20 female) students. The sample was in line with the central limit theorem which stressed that adequate sample should cover between 10 -15% of the total population Tuckman (1975). The Biology Reproduction Performance Test (BRPT) consists of 25 multiple-choice questions.

Results

Table 1: Mean achievement scores of students taught reproduction using virtual KAP simulation and those taught without

Group	Pretest		Post-test		Mean Gain	
	N	$\bar{x}$	SD	$\bar{x}$		SD
Experimental	40	32.83	2.89	63.67	4.59	30.84
Control	43	33.64	4.02	46.09	5.33	12.45

The data in Table 1 is a summary of the mean pre-test and post-test scores as well as mean achievement gain scores of students taught reproduction using virtual KAP and those taught without virtual KAP. The result shows that students taught (experimental) with virtual KAP had the highest mean achievement gain score of 30.84 while those in the control group who were taught without the virtual KAP had the least mean achievement gain score of 12.45. This result suggests that teaching with virtual KAP enhances students' achievement in Biology than using conventional methods.

Table 2: Mean retention scores of students taught reproduction using virtual KAP and those taught without virtual KAP

Group	Pretest			Post-test		Mean Gain
	N	$\bar{x}$	SD	$\bar{x}$	SD	
Experimental	40	48.83	3.19	65.47	3.99	16.64
Control	43	46.24	4.00	47.59	6.26	1.35

Table 2 presents the mean interest gain scores of students taught reproduction using virtual KAP and those taught without virtual KAP. The result shows that the mean pre-interest and post-interest scores of students taught with virtual KAP (experimental) are 48.83 and 65.47 respectively with standard deviations of 3.19 and 3.99 making a gain of 16.64 while those in the control group who were taught without virtual KAP had mean pre-interest and post-interest scores of 46.24 and 47.59 respectively with a mean gain of 1.35.

Table 3: Mean retention scores of male and female students taught reproduction using virtual KAP

Group	Pretest		Post-test		Mean Gain	
	N	$\bar{x}$	SD	$\bar{x}$		SD
Male	40	58.17	9.06	62.76	3.99	4.59
Female		60.64	4.34	63.09	6.26	2.83

The data in Table 3 is a summary of the mean post-test and retention scores as well as mean gain of male and female students taught reproduction using virtual KAP. The result shows that male students obtained a post-test score of 58.17 and retention score of 62.76 making a mean gain of 4.59. The female students obtained a post-test score of 60.64 and retention score of 63.09 making a mean gain of 2.83. It could be observed that male students had a higher mean retention gain score of 4.59 while their female counterparts obtained mean retention score of 2.83.

Table 4: T-test of academic achievement scores of students taught reproduction using virtual KAP compared to those taught without using virtual KAP

Group	N	df	$\bar{x}$	SD	t-value	p-value	Decision
Experimental	38	38	17.13	1.21	8.62	0.00	Sig
Control	36		13.95	1.16			

Significant at $p > 0.05$ level

The t-test results indicates the experimental group had a higher mean score (17.13) compared to the control group (13.95). The P-value of 0.000 and t-value of 8.62 indicates a statistically significant difference between the experimental and control group. The findings suggests that integrating virtual KAP into the teaching of reproduction is an effective method for enhancing students academic achievement. The null hypothesis that suggests no significant differences in achievement is rejected.

Table 5: T-test of academic retention scores of Biology students Taught reproduction using virtual KAP

Group	N	df	$\bar{x}$	SD	t-value	p-value	Decision
Experimental	38	38	17.13	1.21	8.62	0.00	Sig
Control	36		13.95	1.16			

Significant at $p > 0.05$ level

The t-test results indicate a statistically significant difference in academic retention score for students taught reproduction using virtual KAP (experimental group mean= 17.13, SD=1.21) compared to a control group (mean=13.95, SD=1.16). the t-test yielded a t-value of 8.62, a p-value of 0.00 with a t-value of 8.62 indicating a statistical significant difference. This indicates that the virtual KAP significantly enhances retention compared to to the conventional method.

Table 6: T-test of academic retention scores of male and female students taught reproduction using virtual

Group	N	df	$\bar{x}$	SD	t-value	p-value	Decision
Male	43	18	17.53	1.39	1.12	0.27	NS
Female	40		16.85	1.06			

NS= Not Significant at $p > 0.05$ level

The analysis of the retention scores of male and female students taught reproduction using virtual KAP showed that males had a score of (M=17.53, SD= 1.39) scored slightly higher than the females (M=16.85, SD=1.06). however, the difference was not statistically significant, t-value(18)=1.12, P-value 0.27, indicating that gender did not influence students retention levels. This suggests that virtual KAP instructional methods were equally effective for both male and female students in learning reproduction.

Discussion of Findings

The findings of this study revealed that students taught reproduction using virtual KAP simulation achieved significantly higher mean achievement and retention scores compared to those taught with conventional methods. Specifically, the experimental group recorded a mean achievement gain of 30.84, while the control group had only 12.45. This indicates that the virtual KAP approach enhanced understanding and mastery of biological concepts. These findings are consistent with studies such as Yusuf and Afolabi (2010), who reported that computer-assisted instruction significantly improved students' academic performance. Similarly, Okonkwo (2017) found that integrating virtual simulations into biology teaching promoted deeper conceptual understanding and long-term retention.

In terms of retention, students exposed to virtual KAP showed higher mean retention gains (16.64) compared to the control group (1.35). This suggests that simulations foster active learning and better recall of complex concepts. This aligns with the findings of Achor and Ogbeba (2011), who demonstrated that virtual learning resources enhanced students' ability to retain scientific information. The results also confirm the constructivist learning theory, which emphasizes active engagement, visualization, and interactive learning as essential for meaningful knowledge construction.

Furthermore, the analysis of gender differences showed no statistically significant variation between male and female students in retention scores. This indicates that virtual KAP simulation is equally effective for both genders. This outcome corroborates the findings of Adeyemi (2018), who reported no gender disparity in the effectiveness of ICT-based instructional strategies, suggesting that digital tools provide a level playing field for all learners regardless of gender.

Conclusion

The study concludes that the use of virtual KAP simulation significantly enhances students' achievement and retention in biology compared to conventional teaching methods. The strategy not only improved performance but also promoted equitable learning outcomes across genders. These findings underscore the effectiveness of technology-driven instructional tools in making abstract biological concepts more concrete, engaging, and memorable. The study therefore recommends that biology teachers adopt virtual simulation platforms like KAP as a complementary teaching tool to improve student learning outcomes in reproduction and other complex biological topics.

Recommendations

- i. Biology teachers should integrate virtual KAP simulation into classroom teaching of reproduction and other abstract concepts, as it enhances students' achievement and retention.
- ii. Curriculum developers should embed simulation-based instructional strategies in the biology curriculum at secondary school level to ensure consistency and sustainability of technology-supported teaching.
- iii. Since the study shows no significant gender difference, both male and female students should be equally encouraged to engage with virtual learning tools to maximize their learning potential.

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AWARENESS AND ADOPTION OF BIO-BASED MATERIALS FOR MITIGATING GLOBAL WARMING IN SUSTAINABLE BUILDING IN KWARA STATE

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Abstract

The study examined the awareness and adoption of bio-based materials for mitigating global warming in sustainable building in Kwara State. The research aimed to achieve two objectives which were to find out: the level of awareness of bio-based materials in sustainable building in Kwara State, the level of adoption of bio-based materials in sustainable building in Kwara State. The study employed descriptive survey research design. Instrument used for data collection was structured questionnaire. The population for this study comprised of 301 builders, quantity surveyors and architects. 159 builders, 54 quantity surveyors and 88 architects from building construction industry selected in Kwara State. A simple random sampling technique was used to select 121 respondents; comprising of 64 builders, 22 quantity surveyors and 35 architects in Kwara State. The data collected was analyzed by using mean and standard deviation. The findings of this study revealed that builders, quantity surveyors and architects are aware of bio-based materials, although the level of adoption of bio-based materials was low among builders, quantity surveyors and architects. The study recommended that government and construction bodies should create public awareness on the benefits of adopting bio-based materials in building construction, material production industries should focus more on production of bio-based materials in order to increase their availability in the market, government should formulate policies and enforce the construction expertise and house owners to adopt bio-based materials in building construction, Professional bodies should organize workshops and train and re-train personnel on bio-based materials course, experts in building construction should encourage the potential building owners on the benefits of bio-based materials for construction of buildings.

Keywords: *Bio-based materials, Sustainable building, Global warming, Awareness, Adoption*

Introduction

Sustainable building also known as green building or sustainable construction refers to plan, design, construction, operation, and maintenance of buildings in a way that reduces negative environmental impacts (such as high carbon emission), conserves energy and natural resources, and promotes occupant health, sustainable environment and productivity. It integrates environmentally responsible and resource-efficient processes throughout a building's life cycle, from siting to design, construction, operation, maintenance, renovation, and demolition (United Nations Environment Programme, 2022). However, bio-based materials are sustainable materials due to low or zero carbon emission.

Bio-based materials are derived from biological sources and are often considered more environmentally friendly due to low or zero carbon emission compared to traditional materials. Bio-based materials are materials wholly or partly derived from renewable biological origins, or by-products and bio-waste of plant and/or animal biomass that can be used as raw building

materials and decorating items in construction, in their original forms or after being reprocessed (Le *et al.*, 2023). Bio-based materials can be used for different aspect of building stages such as wall, lintel, roof and roofing sheet, column, flooring and as an insulating material. Mansoor & Patel (2020) posited that materials such as bamboo, hemp, and straw can be used for insulation, structural elements, and composites as natural fibers. However, due to low or zero carbon emission of bio-based materials, these materials may not contribute to increase in global warming.

The concept of global warming gained more attention in the late 20th century with the recognition of the effect of greenhouse gases in warming the planet due to high carbon emission by the evolution of modern industrialization. According to National aeronautics and space administration (NASA) (2021), global warming is the long-term heating of earth's climate system due to human activities, primarily fossil fuel burning, which increases heat-trapping greenhouse gas levels in earth's atmosphere.

Awareness is the state of being informed about the particular ideas, events, and things. Gonzalez & Sherrington (2022) describe awareness of bio-based materials to involve recognizing the potential and environmental benefits of using materials sourced from renewable resources, including reduced carbon emissions, energy consumption, and waste production, relative to conventional construction materials.

Adoption is the process by which individuals or organizations begin to accept or use something new such as technology, innovation, or behavior. Adoption of bio-based materials is the process by which individuals or organizations may begin to accept bio-based materials in building construction for sustainability.

Statement of the Problem

Building is an essential structure that provide shelter to human for living. This building is being constructed with different materials based on the choice of clients and construction experts' recommendation. Due to the issue of global warming, concerns are raised about the contribution of building construction to the increase of greenhouse gases which affect climate change. According to Global Alliance for Buildings and Construction (2019), the construction industry is a major contributor to greenhouse gas emissions, accounting for approximately 39% of global carbon emissions.

In Kwara State, the materials used in constructing buildings are commonly traditional building materials such as cement, steel, iron sheet, glass polyvinyl chloride (PVC), plaster of Paris (POP), concrete block and so on. These materials are also part of the building materials likely causing global warming due to their emissions. If this continue, the rate at which building construction may increasingly contribute to global warming will be enormous. The effect of global warming may cause drought, high temperature, rise in sea level, heat wave and flooding in our society which they are already experiencing in Kwara State. In order to eradicate these problems, sustainable practice by adopting bio-based materials in building construction may be the solution.

Aim and Objectives of the Study

The aim of this study is to determine the awareness and adoption of bio-based materials for mitigating global warming potentials in sustainable building in Kwara State. Specifically, the study sought to achieve the following objectives:

- (i) Determine the level of awareness of bio-based materials for sustainable building in Kwara State.
- (ii) Find out the level of adoption of bio-based materials for sustainable building in Kwara State.

Research Questions

The following research questions will guide the study:

- (i) What are the level of awareness of bio-based materials for sustainable building in Kwara State?
- (ii) What are the level of adoption of bio-based materials for sustainable building in Kwara State?

Literature Review

The Nigerian construction sector is predominantly reliant on traditional, non-renewable materials such as cement, concrete, glass and steel. While these materials have been the foundation of modern construction, they are associated with substantial environmental costs, including carbon emissions from production processes, resource depletion, and significant energy consumption (Babatunde *et al.*, 2015). With the country witnessing rapid urbanization and infrastructural development, the demand for construction materials is alarming, putting further strain on the environment. However, there is growing recognition of the environmental and economic benefits that bio-based materials offer. The adoption of these materials has the potential to reduce the industry's carbon footprint, improve energy efficiency, and minimize waste generation. This shift toward bio-based materials is part of a broader global movement towards sustainable construction practices, with various international organizations and local stakeholders advocating for their incorporation into building projects (World Green Building Council, 2020).

Authors have written on bio-based materials as a sustainable material due to their low or zero carbon emission, capable of mitigating global warming in building construction. According Chen *et al.* (2024), bio-based materials have the potential to reduce over 320,000 tons of carbon dioxide emissions by 2050. These materials are biological materials that may be sourced locally. Due to the continuous increase of global warming caused by various human activities such as building construction and so on. According to International Energy Agency (2021), Buildings account for nearly 40% of global energy consumption and about one-third of greenhouse gas (GHG) emissions. Recently, Government and construction bodies have been agitating and embracing sustainable building practice by advocating materials that are low carbon intensive in building construction. From the literature, it has been revealed that low adoption of sustainable building materials occurred in building construction.

Several Nigerian universities and research institutions have begun to explore the potential of bio-based materials in construction. For instance, the University of Lagos has conducted studies on the use of bamboo as an alternative construction material (Akinmoladun *et al.*, 2020). Bamboo is a fast-growing and highly sustainable material that has shown promise in reducing the carbon

footprint of construction. Other studies have focused on the use of compressed earth blocks (CEBs) and other plant-based materials that are readily available in the country's rural areas (Durojaiye *et al.*, 2019).

However, despite their advantages, bio-based materials may face multiple challenges that hinder their widespread adoption in the construction industry. Gösswein *et al.*, (2022) observed that bio-based materials often face challenges regarding long-term durability and technical performance, such as moisture sensitivity, fire resistance, and strength. Arizaga *et al.* (2020) opined that the widespread adoption of bio-based materials faces economic hurdles, particularly high initial costs and financial constraints that impact their competitiveness in the market.

Innocent *et al.* (2020) carried out a study on barriers to the adoption of sustainable construction. The results revealed that key barriers to sustainable construction in the Nigerian Construction Industry are poor government support for sustainable construction, lack of relevant laws and regulations to drive sustainable construction, lack of demand for sustainable construction from clients, low level of awareness of sustainable construction and fear of the cost of adopting sustainable construction

A study by Umar *et al.* (2021) on assessing the awareness of architects on sustainable building materials in Minna, Nigeria, revealed that a significant number of professionals have below-average knowledge of sustainable materials. The authors specifically found out that 44% of the respondents had minimal awareness, while only 11% demonstrated a very good understanding of these materials. This limited awareness may be considered a barrier to the adoption of bio-based materials in the Nigerian construction sector. Awareness of bio-based materials in the construction sector is crucial for promoting their adoption, reducing environmental footprints, and enhancing the overall sustainability of the built environment (Müller *et al.*, 2022).

Research Methodology

The study adopted a descriptive survey research design. The population for this study comprised of 301 builders, quantity surveyors and architects. 159 builders, 54 quantity surveyors and 88 architects from building construction industry selected in Kwara State. A simple random sampling technique was used to select 121 respondents; comprising of 64 builders, 22 quantity surveyors and 35 architects in Kwara state. A structured questionnaire was used to collect data from respondents. The data collected was analyzed by using mean and standard deviation. The study used a four-point likert scale type of questionnaire: Highly Aware (HA) (4 points), Moderately Aware (MA) (3 points), Slightly Aware (SA) (2 points), Not at All Aware (NA) (1 point) for research question one while Highly Adopted (HA) (4 points), Moderately Adopted (MA) (3 points), Slightly Adopted (SA) (2 points), Not at All Adopted (NA) (1 point) for research question two.

Results and Discussion

Research Question One

What is level of awareness of bio-based materials for sustainable building in Kwara State?

Table 1: Summary Statistics of Respondents on the Level of Awareness of Bio-based Materials for Sustainable Building in Kwara State N =121

S/N	Items	Mean ($\bar{x}$)	SD	Remarks
1	Timber	3.51	0.50	HA
2	Hempcrete	3.46	0.52	MA
3	Straw bale	3.55	0.53	HA
4	Adobe	3.21	0.52	MA
5	Mycelium	3.32	0.49	MA
6	Bamboo	3.57	0.50	HA
7	Wool	3.49	0.50	MA
8	Cork	3.12	0.44	MA
9	Bioplastic materials	3.14	0.41	MA
10	Flax Fiber	2.20	0.96	SA
11	Wheat Straw Board	3.76	0.45	HA
12	Kenaf	3.21	0.47	MA
13	Rice Husk Ash Concrete	3.31	0.47	MA
14	Bagasse Board	3.29	0.51	MA
15	Corn Starch-Based Plastics	3.35	0.48	MA
16	Palm Fiber	3.69	0.46	HA
17	Sunflower Husk Panels	3.31	0.48	MA
18	Cob	3.34	0.53	MA
19	Clay-Straw Blocks	3.71	0.46	HA
20	Rammed Earth	3.60	0.49	HA
21	Algae-Based Panels	3.12	0.49	MA
22	Chitosan-Based Biopolymers	2.50	0.88	MA
23	Earthen Plaster	3.38	0.50	MA
24	Casein-Based Adhesives	3.27	0.56	MA
25	Thermally Modified Wood	3.60	0.49	HA
26	Wood Wool Panels	3.60	0.49	HA
27	Lignin-Based Composites	2.40	0.92	SA
28	Cellulose Insulation	3.22	0.51	MA
29	Biochar Panels	3.37	0.59	MA
30	Miscanthus (Elephant Grass)	3.27	0.56	MA
Grand Mean/SD		3.29	0.54	Moderately Aware

Key: N = Number of respondents; SD = Standard Deviation; HA = Highly Aware; MA = Moderately Aware; Slightly Aware

Table 1 showed the means responses of the respondents on 30 items posed to determine the level of awareness of bio-based materials for sustainable building in Kwara State with a grand mean of 3.29 which implied the respondents were moderately aware of bio-based materials in sustainable building in Kwara State. The standard deviation of the items ranged from 0.41 to 0.92 which further implied that the 30 items had their standard deviation less than 1.96 indicating that the respondents were not too far from the mean and were close to one other in their responses. This closeness of the responses adds value to the reliability of the mean.

Research Question Two**What is the level of adoption of bio-based materials for sustainable building in Kwara State?****Table 2: Summary Statistics of Respondents on the Level of Adoption of Bio-based Materials for Sustainable Building in Kwara State N =121**

S/N	Items	Mean ($\bar{x}$)	SD	Remarks
1	Timber	3.71	0.46	HA
2	Hempcrete	1.24	0.42	NA
3	Straw bale	1.57	0.64	SA
4	Adobe	1.77	0.66	SA
5	Mycelium	1.30	0.48	NA
6	Bamboo	2.50	0.62	MA
7	Wool	1.64	0.48	SA
8	Cork	1.39	0.49	NA
9	Bioplastic materials	1.58	0.53	SA
10	Flax Fiber	1.45	0.50	NA
11	Wheat Straw Board	1.46	0.50	NA
12	Kenaf	1.46	0.50	NA
13	Rice Husk Ash Concrete	1.49	0.50	NA
14	Bagasse Board	1.42	0.49	NA
15	Corn Starch-Based Plastics	1.47	0.50	NA
16	Palm Fiber	1.58	0.51	SA
17	Sunflower Husk Panels	1.41	0.48	NA
18	Cob	1.40	0.49	NA
19	Clay-Straw Blocks	1.54	0.53	SA
20	Rammed Earth	1.38	0.48	NA
21	Algae-Based Panels	1.50	0.50	SA
22	Chitosan-Based Biopolymers	1.55	0.50	SA
23	Earthen Plaster	3.07	0.41	MA
24	Casein-Based Adhesives	1.36	0.48	NA
25	Thermally Modified Wood	3.35	0.48	MA
26	Wood Wool Panels	2.88	0.36	MA
27	Lignin-Based Composites	1.50	0.50	SA
28	Cellulose Insulation	1.43	0.55	NA
29	Biochar Panels	1.45	0.50	NA
30	Miscanthus (Elephant Grass)	1.20	0.40	NA
Grand Mean/SD		1.73	0.50	Slightly Adopted

Key: N = Number of respondents; SD = Standard Deviation; HA = Highly Aware; MA = Moderately Aware; SA = Slightly Aware; NA = Not at all Adopted

Table 2 showed the means responses of the respondents on 30 items posed to determine the level of adoption of bio-based materials for sustainable building in Kwara State with a grand mean of 1.73 which implied the respondents slightly adopted bio-based materials in sustainable building in Kwara State. The standard deviation of the items ranged from 0.36 to 0.66 which further implied

that the 30 items had their standard deviation less than 1.96 indicating that the respondents were not too far from the mean and were close to one other in their responses. This closeness of the responses adds value to the reliability of the mean.

Discussion of Findings

Table 1 revealed that builders, quantity surveyors and architects agreed that timber, rammed earth, adobe, thermally modified wood, wood wool panels, wheat straw board and palm fiber are the highly aware bio-based materials while flax fibre, chitosan-based biopolymers and lignin-based composites are the slightly aware bio-based materials in Kwara State. This implies that builders, quantity surveyors and architects are aware of bio-based materials. The finding of this study is in agreement with Amuda-yusuf *et al.* (2020) who found out that that professionals from client organization recorded highest mean score in terms of awareness on sustainability concept followed by those from academia, consulting and contracting.

Table 2 showed that builders, quantity surveyors and architects highly adopted timber and Thermally Modified Wood and bamboo while the rest of the bio-based materials are slightly or not adopted in building construction. This could be as a result of challenges confronting the use of bio-based materials in building construction.

Conclusion

Based on the findings, there was highly awareness of bio-based materials by builders, quantity surveyors and architects. The study found that there was low adopted of bio-based materials by builders, quantity surveyors and architects. This could be as result of challenges facing bio-based materials in building construction such as limited available of materials, lack of knowledge and expertise, public perceptions and reluctances, low fire resistance and other factors.

Recommendations

Based on the results of the findings of this study, the following recommendations are offered by the researcher:

- (i) Government and construction bodies should create public awareness on the benefits of adopting bio-based materials in building construction. This will increase the level of adopting of bio-based materials to mitigate global warming due to their low or zero carbon emission.
- (ii) Material production industries should focus more on production of bio-based materials in order to increase their availability in the market.
- (iii) Government should formulate policies and enforce the construction expertise and house owners to adopt bio-based materials in building construction.
- (iv) Professional bodies should organize workshops and train and re-train personnel on bio-based materials course
- (v) Experts in building construction should encourage the potential building owners on the benefits of bio-based materials for construction of buildings.

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SYSTEMATIC REVIEW OF THE IMPACT OF SCREEN-PAL ON LEARNING OUTCOMES OF PRE-SERVICE CHEMISTRY TEACHERS IN COLLEGES OF EDUCATION IN NIGER STATE, NIGERIA

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Abstract

This paper presents a systematic review of existing literature on the use of screen recording and video-based learning platforms, particularly Screen-pal, and their effects on students' learning outcomes. The review focuses on pre-service chemistry teachers in Colleges of Education in Niger State, Nigeria. The aim is to synthesize available evidence on how Screen-pal influences academic achievement, conceptual understanding, retention, and engagement. The review highlights existing gaps in research and provides directions for future studies to establish the practical potential of Screen-pal in Nigerian teacher education.

Keywords: *Screen-pal, Video-based learning, Screen recording, Pre-service chemistry teachers, Learning Outcomes, Academic achievement, Retention, Engagement, Interest, Information and Communication Technology (ICT), Digital instructional tools*

Introduction

The use information and communication technology (ICT) in the 21st century teaching and learning has revolutionized various fields of human endeavour including education. The Nigerian Colleges of Education Pre-service Chemistry teachers are frequently faced with limitations such as laboratory apparatus, inadequate instructional materials. These limitations have made it difficult for Pre-service teachers to gain conceptual meaning of the subject and impeded their interest in the subject itself (Oludipe and Oludipe, 2020). Educational resources such as Screen-Pal have been introduced to enhance more interactive and learner centered learning. Screen-pal is a screen-recording and video-creation platform, enables educators to develop instructional videos, demonstrations, and feedback that can be accessed by students anytime and anywhere (Martinez, 2021). This is particularly important for Chemistry, which requires clear demonstrations, visualizations of concepts, and step-by-step problem-solving explanations (Taber, 2018).

Information and Communication Technology (ICT) has become a critical driver in modern education. The use information and communication technology (ICT) in the 21st century teaching and learning has revolutionised various fields of human endeavour including education. The Nigerian Colleges of Education Pre-service Chemistry teachers are frequently faced with limitations such as laboratory apparatus, inadequate instructional materials. These limitations have made it difficult for Pre-service teachers to gain conceptual meaning of the subject and impeded their interest in the subject itself (Oludipe and Oludipe, 2020). Educational resources such as Screen-Pal have been introduced to enhance more interactive and learner centered learning. Screen-pal is a screen recorder and video maker whereby teachers can make dynamic lesson material like recorded lectures, experimental demonstrations and tutorial videos. These can be accessed asynchronously; enabling Pre-service teachers to learn at their own pace, and also revise

complex topics over and over again. This tool meets the needs of the modern-day education, for instance flipped classroom and blended learning as they have been proved to increase learners' autonomy and academic achievement in chemistry (Adedoyin and Soka, 2020).

Screen-pal is a digital screen recorder and video production software used in teaching, learning, and content delivery. It enables instructors to screen-record activities, capture narration, and incorporate visual aids, thus creating interactive instructional resources that can be stored and shared with learners (Johnson & Green, 2021). The resource is especially applicable to the educational setting since it integrates both audio and visual features and facilitates the dual-channel learning process and the enhanced comprehension of complex ideas (Mayer, 2020). Screen-pal can be used in training pre-service teachers to create interactive lessons, demonstrations, and tutorials that can be replayed at the convenience of the learner. This flexibility promotes individual learning and raises retention particularly in fields such as chemistry where abstract concepts may need repetitive visualizations (Adedoyin and Soykan, 2020). In contrast to the conventional teaching styles, Screen-pal allows students to watch recorded explanations again and again, take a moment, and learn at their own pace, which facilitates interest and knowledge acquisition (Oyelami and Ojo, 2022). Moreover, Screen-pal provides collaborative and dialogical learning because pre-service teachers are able to create, share and discuss video content with other students. This helps to promote active learning and develop digital skills that are essential to 21st -century education (Choi and Lee, 2021). Screen-pal can greatly boost academic achievement among pre-service chemistry teachers by enhancing their engagement, facilitating further learning, and offering repeated access to instructional material. However, there is limited empirical data on its use specifically for Chemistry teacher education in Nigeria, thus providing a gap that this systematic review seeks to address.

Chemistry is a central science that explores the composition, structure, properties, and changes of matter. It plays a vital role in various fields, including medicine, agriculture, industry and education. Thus, teaching and learning of chemistry will contribute greatly to science literacy and progress in a nation's development (Ameh and Dantani, 2020). Many pre-service teachers struggle with abstract Chemistry concepts, resulting in poor academic performance and retention rates (Taber, 2019). More so, Chemistry is considered complex because it deals with abstract processes. Since atomic structure, chemical bonding and stoichiometry are not visible, it can be difficult to both teach and learn them. For this reason, using different teaching techniques, including those that rely on technology, can boost students' knowledge.

Review of Related Literature

Several studies have reported that screen recording and video lectures enhance students' understanding of abstract scientific concepts. A study by Ominowa. and Bamidele (2016) found that there was a significant difference in the performance of students in the two groups. Students taught with VMI performed significantly better than those taught with CDT only ($t =$, $p < 0.05$). Also, there was a significant difference in the effectiveness of VMI in enhancing retention ability of students in practical Chemistry. The study concluded that VMI was effective in teaching practical chemistry (Volumetric Analysis) and that integrating CDT with VMI will enhance students learning. Similarly, Abiola (2017), compared the effects of Animation-based Flipped Classroom Strategy (AFCS) and Video-based Flipped Classroom Strategy (VFCS) on biology learning outcomes of pre-degree students and found that there were significant main effects of

treatments on aptitude, attitudes and practical skills where AFCS had the largest gains and VFCS followed closely. Achievement and practical skills were also swayed by gender, with female students performing better. Lawal *et al.*, (2022) examined how video-self-analysis and peer-analysis contributed to the growth of presentation skills in pre-service chemistry teachers in the Colleges of Education located in Northern Nigeria in the North-West Region. The results found that pre-service chemistry teachers that watched video self- and peer-analysis developed excellent presentation skills than when the control group was used. Tanko and Abdullahi (2021) study compare to the current study in the following aspects; Both studies target pre-service teachers, particularly those training to teach science, both studies use the same core instructional material, which takes its item primarily in chemistry. Academic performance improvement is a central outcome measure in both studies, While the authors used video tutorials in general, the current study focuses on a specific tool Screen-pal.

From the literature reviewed, several gaps are evident: There is little to no research on the application of Screen-pal specifically for pre-service Chemistry teacher education in Niger State. Few studies investigate long-term retention and engagement outcomes using Screen-pal. Most available studies are conducted in developed countries with better internet infrastructure, which may not reflect the realities of Nigerian classrooms.

Conclusion and Implications

This review establishes that Screen-pal has significant potential for improving the quality of Chemistry education for pre-service teachers in Niger State. By enabling students to review lessons repeatedly and access laboratory demonstrations remotely, Screen-pal can bridge learning gaps caused by inadequate infrastructure. The review recommends future empirical studies to test the effectiveness of Screen-pal in real-world settings, using quasi-experimental designs to measure achievement, retention, and student satisfaction.

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PREPARING MATHEMATICS TEACHERS FOR INCLUSIVE EDUCATION IN THE ERA OF ARTIFICIAL INTELLIGENCE

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Abstract

Artificial Intelligence is transforming education globally by providing new prospects for personalized learning, adaptive test-taking, and assistive technology. In mathematics education, these technologies can facilitate inclusive teaching by tackling diversity among learners, especially those with disability, language limitations, or socio-economic disparities. The success of AI in enhanced inclusion is mainly based on mathematical teachers' readiness to incorporate these tools substantively. This paper discussed that mathematics teachers' needed competencies during the AI age, challenges for teacher professionalization in Nigeria, and international lessons for enhanced inclusive education. Based on the Universal Design for Learning framework and recent literature both from international and Nigerian perspectives, we propose here that mathematical teacher readiness for enhanced inclusion during the AI age necessitates comprehensive pre-service and in-service education, ethical consideration, localized tools, and supportive policy initiatives.

Keywords: *Mathematics education, inclusive education, artificial intelligence, teacher education, and professional development.*

Introduction

Learning has always been identified as the key to social and economic progress. Mathematics stands out as a pivotal subject in learning, being foundational to science, technology, engineering, and innovation. Mathematics is one of the most difficult subjects to learn among all learners all over the world despite its importance, with access and equity challenges causing noticeable divisions. The problem is worst when it comes to Nigeria, with a compulsory requirement to study mathematics up to junior and senior secondary level, but performance is always below expectation in standardized assessments like WAEC and NECO (Otikor, 2023). For learners with disability, those who are linguistically diverse, and those who are from poor backgrounds, mathematical success is harder to achieve.

Of late, Artificial Intelligence (AI) has been proclaimed as a revolutionizing agent with the potency to overcome various impediments to education access and equity. AI instruments are being employed increasingly to deliver personalized feedback, adaptive practice activities, computerized assessments, and accessibility support for learners with special needs (United Nation Education Scientific & Cultural Organization, 2023). In mathematics education, AI can identify trends of problem-solving habits, prescribe personalized interventions, and even present mathematical ideas in multimodal formats like visualizations, oral explanations, and simulated interactions. However, these prospects are not automatic. The capacity for AI to transform mathematics education toward greater equity relies upon teacher readiness to incorporate it effectively in their teaching.

Preparing mathematics teachers for inclusive education in the age of AI is thus a priority task urgently needed. Teachers need to acquire digital and AI literacy and develop inclusive teaching

practices to ensure equity. In environments like Nigeria, with crowded classes, infrastructural challenges, and a lack of adequate professional training for teachers, the training of digital technology becomes even more necessary (Egara, 2024). This paper looks at the nexus of mathematics education, inclusion, and AI and takes cognizance of global and Nigerian realities to identify the capacities needed by teachers, models of preparation possible, and challenges to be overcome.

Inclusive Education and Mathematics

Inclusive education is when students attend and are accepted by their nearby schools at age-appropriate, regular classes and are encouraged to learn, contribute and take full participation in all aspects of life at the school. According Hassan, and Afu (2019), inclusive education is all about how we develop and design our schools, classrooms, programs and activities so that all students learn and participate together. They went further to say that inclusive education is all about ensuring access to quality education for all students by effectively meeting their diverse needs in a way that is responsive, accepting, respectful and supportive. Inclusive education is all about doing everything we can to ensure all students gain quality education by efficiently addressing their diverse needs in a responsive, accepting, respectful and supportive manner.

Inclusive education is founded on the belief that all students, regardless of any disability, socio-economic situation, or language, are entitled to access learning effectively. In mathematical education, inclusion means granting equal access to ideas capable of assisting learners to overcome obstacles and are attracted by suitable cultural illustrations and differentiated modes of teaching. At the global scale, there has been guidance from statements like Salamanca Statement (UNESCO, 1994) and United Nation Sustainable Development Goal 4 to highlight "inclusive and equitable quality education." At the national level in Nigeria, National Policy on Education similarly highlights inclusivity, yet its implementation is uneven and unevenly distributed at the grassroots scale, particularly at the level of mathematics classes where large classes and scarce resources present challenges to teachers (Otikor, 2023).

Studies have found digital interventions to be effective for students with certain difficulties in mathematics. Benavides-Varela et al. (2020), for instance, showed computer-assisted interventions to drastically enhance performance for children with dyscalculia. AI goes one step further by allowing diagnostic information and personalized support to adapt to learners' needs. For instance, AI programs can pick up typical mistakes involving addition of fractions and provide personalized exercises for students with difficulty, and with conceptual understanding (Bhushan et al., 2024). Without mediation by teachers, however, these programs can simply exacerbate inequities by favouring students who have greater access to and connectivity with devices.

Inclusive mathematics education during the AI era therefore needs to draw inspiration from philosophies such as Universal Design for Learning (UDL). The UDL advocates for varied means of representation (e.g., visual, auditory, symbolic), of engagement (e.g., group work, game-based practice), and expression (e.g., written, verbal, computer-based solutions) (Center for Applied Special Technology, 2018). Mathematics instructors with training in UDL are accordingly rightfully empowered to leverage AI tools for presenting ideas to diverse learners from students with visual impairments to students learning in rural Nigerian schools and who are more familiar with mobile phones than desktop computers.

Artificial Intelligence Utilized to Study Mathematics

AI Applications to mathematical education are growing fast and they are:

1. **Adaptive Learning Platforms:** Platforms such as ALEKS or Century Tech adjust problem sets to the learner's performance level, ensuring personalized pacing. Nigerian teachers could use similar systems tailored to the WAEC and NECO curriculum.
2. **Automated Grading:** There are AI resources available to automate open-ended answers and free instructors' time for other interaction.
3. **Assistive Technologies:** Speech-to-math and math-to-speech converters allow math to come alive for students with visual impairments and motor impediments.
4. **Generative AI Platforms:** Platforms such as ChatGPT or MathGPT can provide real-time explanations of topics, and instructors can create variations to fit diverse learners (Egara, 2024).

Although these are exciting innovations, there are risks involved. AI programs are often trained with data sets involving cultural or linguistic contexts other than those of Nigeria. As UNESCO (2023) warns that these programs can incorporate bias or provide answers at variance with the local curriculum. Teachers are therefore asked to take a mediating role who localize and interpret AI products to students.

Competencies Mathematics Teachers Need

Preparing mathematics teachers to teach in an age of inclusion with AI requires a set of technological, pedagogic, and ethical skills to be developed and can be integrated as follows in Table 1.

Table 1: Competencies for Mathematics Teachers in the AI Era

Competency Area	Description	Inclusive Application
AI and Digital Literacy	Grasping how AI tools work, their advantages and disadvantages Acquiring	Acquiring AI for learners with disability
Inclusive Teaching Programming	Unit lessons align with UDL principles	Implementing multimodal learning strategies
Data Literacy	Reading AI-based diagnostic inferences	Identifying error and misconception trends
Ethical Awareness	Observing privacy, bias, and fairness issues	Offering equal treatment to all students
Collaborative Practice	Professionals' sharing of experience and tactics through professional learning communities	Peer mentoring for AI incorporation

The table above highlights further that technology is never a guarantee for inclusion. Teachers have to transition digital skills to inclusive teaching mindsets to promote equity.

Getting mathematics educators ready to teach amidst an AI-led era necessitates collective effort towards cultivating the following capabilities as listed in table 1;

1. **Artificial Intelligence and Digital Literacy:** Educators need to comprehend how AI programs are constructed and how to take advantage and measure their limits. For instance, a teacher needs to identify whether an AI-produced solution is mathematically incorrect or pedagogically inappropriate.
2. **Inclusive Teaching Programming:** Teachers require methods to work with diverse learners like offering manipulatives to allow hands-on learning or bilingual descriptions to allow multilingual classes.
3. **Data Literacy:** AI applications create a large quantity of data. Teachers need to be able to read from the performance and dashboards of error to adjust instruction accordingly (Bhushan *et al.*, 2024).
4. **Ethical Awareness:** Teachers have to flag issues with bias, equity, and data privacy when using AI. For instance, a teacher based in Nigeria would be in a position to educate parents on how a website secures student information.
5. **Collaborative Practice:** The integrating of AI requires teachers to work in professional communities so that they can share their knowledge, troubleshoot challenges, and develop collective expertise (Egara, 2024).

These competencies need to be intentionally incorporated into teacher education programs and not left to await by chance.

Teacher Preparation Model

Around the world, various teacher preparation models have been utilized to incorporate AI with mathematics education. There are some points of similarity and differences for Nigeria.

Table 2: Comparing Teachers Preparation Models: International and Nigerian Context

Dimension	Global Practices	Nigerian Context
Pre-service Education	AI integrated with teacher education programs (e.g., Finland, Singapore)	Acknowledged AI exposure during teacher college studies
In-service professional Development	Continuous PD with AI labs and workshops	Short workshops, often irregular
Access to Infrastructure	High-speed internet and computer access are typical	Substandard rural school infrastructures
Localized Tools	National-curriculum aligned AI tools	Imported tools with limited localization mainly

Collaboration Research	and EdTech university collaborations	companies and No comprehensive collaborations, only pilot programs

The table indicates the requirement for localizing global plans by Nigeria at all teacher education levels, particularly by pre-service and service educators. The following is an explanation relating to teacher's preparation models as depicted by table 2 above;

Pre-service Education

Nigerian teacher education programs ought to transform to integrate AI and inclusion teaching. Mathematics education majors must practice with AI tools during their training and develop lesson plans with AI to integrate inclusion. For example, they can practice with AI-based geometry visualizers to work with blind learners.

In-service Professional Development

Professional education is crucial for practicing teachers. One-off brief workshops were ineffective. Teachers require ongoing CPD programs blending the theoretical foundation, hands-on activities, and reflection (Tan et al., 2024). Local efforts can take advantage of blended formats by mixing AI-driven online learning modules with coaching at schools in-person.

Access to Infrastructure

Access to facilities is an important factor contributing to teachers' professional advancement. On-site digital facilities like computer access and digital resources allow teachers to access digital materials and resources, join digital webinars and collaborate with peers globally. Modern training rooms facilitate hands-on learning activities, and subject-specific teaching resources and materials improve quality teaching. Infrastructure investment facilitates teachers' continued improvement and benefits students and education system eventually.

Localized Tools

Localized instruments in teacher professional development are technologies and resources customized for certain regions, cultures or languages. The tools facilitate enhanced training for instructors through enhanced accessibility, culturally relevant resources and effectiveness. Examples are language-specific resources, regional educational networks and online courses. To deploy these tools, local needs have to be identified and local instructors have to be engaged while offering requisite training and support to enhanced teacher participation and also to enhanced learning outcomes.

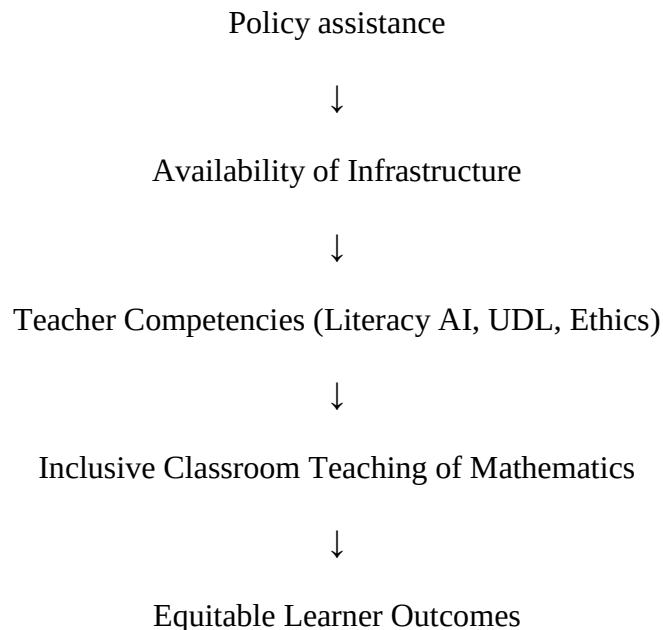
Collaboration and Research

EdTech startup collaborations can further assist in developing locally compatible AI to accommodate Nigerian curricula and languages. Collaborations can ensure AI is neither another imported technology nor a technology based elsewhere but a technology rooted in Nigerian realities (Otikor, 2023).

AI Implementation Framework Model

The AI implementation framework for preservice mathematics educators.

Fig 1: Framework for Preparing Mathematics Teachers for Inclusive AI-Powered Education.



The AI implementation framework illustrates the connection from Policy assistance → Availability of Infrastructure → Teacher's Competencies → Inclusive Classroom Teaching of Mathematics → Equitable Learner Outcomes

Barriers and Ethical Issues

Despite its potential, there are some challenges restraining AI adoption for inclusive mathematics learning:

- i. **Infrastructural Lapses:** Most Nigerian schools have no steady power supply, internet connection, nor equipment to adopt AI.
- ii. **Algorithmic Bias:** The AI tools lack diversity when it comes to perceiving the learners in Nigeria, causing misinterpretations (UNESCO, 2023).
- iii. **Concern for Privacy:** Information transmitted by students to third-party websites is subject to risk for lack of policy direction (United State Department Education, 2023).
- iv. **Teacher Workload:** AI dashboards can overwhelm teachers with data unless carefully designed.
- v. **Resistance to Change:** Teachers who are technology-unfamiliar can resist incorporation, particularly in rural areas.

These challenges open an argument for cautious, ethical, and context-sensitive AI integration.

Conclusion

Artificial Intelligence provides rare chances to make mathematics education more inclusive through adaptive, accessible, and personalized learning environments. The secret to unlocking this is through teacher preparedness. Mathematics educators need to be AI literate, incorporate inclusive teaching techniques, know how to interpret data, and have ethical perspectives. For Nigeria with its infrastructural and system challenges remaining intact, deliberate investment by governments in teacher preparation and localized AI solutions is imperative. By integrating inclusive practices through AI integration, mathematics classes can become environments through which all learners irrespective of their ability and backgrounds will flourish towards mathematical learning.

Recommendations

The following recommendation were made;

1. **Policy Environments:** Education ministries in Nigeria need to formulate national plans regarding AI and education with a priority towards inclusion.
2. **Curriculum Redesigning:** Mathematics teacher education curricula should incorporate AI literacy, teaching for diversity and inclusion, and UDL principles.
3. **Localized AI Platforms:** The developers need to work with Nigerian instructors to create AI platforms based on WAEC and NECO syllabi and based on local languages.
4. **Ethical Education:** Teachers must be trained in data privacy, equity, and responsible AI application.
5. **Communities of Practice:** Develop teacher networks to share and contextualize AI experience.
6. **Foster Collaboration:** fostering of collaboration between government, universities, and EdTech companies.

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LEVERAGE WEB-BASED INFOGRAPHICS AND WEBQUEST INTEGRATED INSTRUCTION TO ENHANCE ACADEMIC ACHIEVEMENT AND RETENTION PRE-SERVICE PHYSICS TEACHER IN NIGERIA COLLEGES OF EDUCATION

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Abstract

The demand for innovative teaching strategies in physics education has become more pressing in the twenty-first century as pre-service teachers require not only content mastery but also critical thinking and problem-solving skills. This paper explores the potential of Web-based Infographics and WebQuest integrated instruction to enhance academic achievement and retention among pre-service physics teachers in Nigerian Colleges of Education. Infographics provide visually appealing, simplified representations of complex physics concepts, reducing cognitive overload and improving comprehension. WebQuest, on the other hand, engages students in guided inquiry-based learning using web resources, fostering higher-order thinking and collaborative learning. Drawing on current literature, this paper argues that the combination of these approaches could improve learner engagement, retention, and performance when compared to conventional lecture-based methods. The discussion concludes with recommendations for curriculum developers, teacher educators, and policymakers to integrate infographics and WebQuest into teacher preparation programmes.

Keyword: Web-Based Infographics, WebQuest, Academic Achievement and Retention.

Introduction

The teaching and learning of physics in Nigerian Colleges of Education continue to face challenges such as overcrowded classrooms, reliance on traditional lecture methods, and limited use of technology-enhanced pedagogies. Physics is one of the major natural scientific fields that is very important to the technology empowerment of any nation. Physics is the study of the interaction between mass and energy. Shuriye (2021) defined Physics as a diverse activity of thinking in mankind thereby making intelligent comprehension of how natural things happen or occur and discovering the causes behind such phenomena. More broadly, it is the general analysis of nature, conducted in an organized manner to understand how the universe works and its potential for exploration that will greatly benefit man. The shift towards learner-centred and technology-driven pedagogies is therefore essential in preparing pre-service teachers who will eventually influence secondary school science education. This paper explores how web-based infographics and WebQuest integrated instruction can serve as effective tools for addressing these challenges by presenting information visually and promoting inquiry-based learning.

Science Education and Physics in Teacher Preparation

Science education is central to national development because it equips individuals with scientific literacy, Physics that require no mathematical solution but that one can just use his or her mental ability to learn and apply underlying principles as required (Aina, 2017). There are various aspects of physics each with its unique application from mechanics, optics, atomic and quantum, electricity, electromagnetism, modern, semi-conductor, material, electronics, and nuclear physics. The application of these aspects can be found in engineering, medicine, agriculture, electronics, construction, survey and mining. Hence, physics is applied in virtually all areas of human endeavors. Physics is essential for understanding the complexities of modern technology and essential for the technological advancement of a nation (Umeh, *et al.*, 2017). There are various aspects of physics each with its unique application from mechanics, optics, atomic and quantum, electricity, electromagnetism, modern, semi-conductor, material, electronics, and nuclear physics. The application of these aspects can be found in engineering, medicine, agriculture, electronics, construction, survey and mining. Hence, physics is applied in virtually all areas of human endeavors. It was then very necessary that teachers training institutions produce physics teachers that are competent both content and methodology to secure our future of an advanced technology country that can be about achievement. However, when physics is taught through passive, lecture-dominated methods, learners may fail to connect theoretical knowledge with real-life applications, leading to poor retention and performance.

Infographics in Physics Education

Infographics are visual representations of information that combine graphics, text, and data in a simplified and engaging format. The use of such infographics, thus, promotes understanding and enhances organization and long-term retention of data. It stresses meaningful learning which serves to facilitate learning and minimize boredom on the part of the learners (Alzoubi *et al.*, 2023). An infographic can show a student's ability to sort information, shape relationships, recognize trends, and present the data as more concrete knowledge (Hamadi, 2019). Building on the power of infographics to enhance analytical thinking and facilitate meaningful learning require the integration of WebQuest to satisfy students' curiosity for inquiry-based learning.

Benefits of Infographics over Conventional Teaching

Infographics offer several advantages over the conventional chalk-and-talk approach. They promote dual coding of information (visual and verbal), which enhances cognitive processing and long-term memory retention (Dina and Ensaf, 2021). They also encourage self-paced learning, as students can revisit the infographic to consolidate their understanding. Unlike conventional methods that rely heavily on note-taking and rote memorisation, infographics foster deeper conceptual learning and support learners with different cognitive preferences (Alshehri and Ebaid, 2020).

WebQuest Integrated Instruction

WebQuest is an inquiry-oriented instructional strategy in which learners use web resources to solve problems or complete tasks guided by a structured process (Serkan, 2016). A typical WebQuest consists of an introduction, task, process, resources, evaluation, and conclusion. By design, it promotes critical thinking, collaboration, and independent learning. When integrated into physics instruction, WebQuest activities can lead pre-service teachers to explore real-world applications

of physics principles, conduct virtual experiments, and synthesise information from multiple online sources.

Benefits of WebQuest Integrated Instruction over Conventional Teaching

Compared with conventional lecture-based teaching, WebQuest encourages active participation, inquiry, and problem-solving (Mohamed, 2020). It helps students develop digital literacy skills while engaging them in meaningful learning tasks that mirror real-life scenarios. WebQuest also enhances cooperative learning, as students often work in teams to analyse data, discuss findings, and present solutions. This promotes learners' motivation, collaborative learning, epigrammatic information presentation, and acquire ownership of their learning (Fadzil, 2018).

Effects of Infographics and WebQuest on Pre-Service Physics Teachers

When combined, Infographics and WebQuest create a powerful blended-learning experience. Infographics simplify and visualize difficult concepts, while WebQuest drives deeper exploration and application of knowledge. Dina and Ensaf, (2021) argued that good infographics are useful in supporting the development of students. In addition, infographics are considered to be an effective communication tool for communication with the information. The instructional effects of visuals (Ismaeel and Al-Mulhim, 2019) are on the upper level when they are prepared according to the scheme of learners. Similarly, learning with infographics may allow learners to understand the information in an organized way and form the basis for schemes needed to be created in the minds of individuals. For pre-service physics teachers, this approach not only enhances academic performance but also equips them with innovative instructional techniques they can transfer to their future classrooms.

Summary

This paper has highlighted the potential of web-based infographics and WebQuest integrated instruction in improving the teaching and learning of physics in Nigerian Colleges of Education. While conventional lecture-based methods remain dominant, these innovative approaches offer more interactive, visual, and

Conclusion

Web-based infographics and WebQuest integrated instruction provide an opportunity to transform physics education in teacher preparation programmes. They offer solutions to persistent challenges such as low achievement and retention rates by making learning interactive, learner-centred, and visually stimulating. Their adoption aligns with global trends in technology-driven education and can contribute to the production of better-prepared physics teachers.

Recommendations

1. Integration into Curriculum: Teacher education programmes should formally integrate Infographics and WebQuest as part of physics pedagogy courses.
2. Capacity Building: Teacher educators should receive training in designing and implementing web-based instructional tools.
3. Provision of ICT Infrastructure: Colleges of Education should invest in reliable internet connectivity and digital devices to support WebQuest activities.
4. Further Research: Future studies should empirically investigate the comparative effectiveness of infographics, WebQuest, and their combination on learner outcomes.

5. Policy Support: Education policymakers should encourage the adoption of ICT-supported pedagogies through funding and curriculum reforms.

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AWARENESS AND ADOPTION OF ARTIFICIAL INTELLIGENCE TOOLS FOR BUILDING PROJECT MANAGEMENT AMONG ARCHITECTS AND BUILDERS IN FEDERAL CAPITAL TERRITORY, ABUJA, NIGERIA

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Abstract

The study determines the level of awareness and extent of adoption of AI tools for building project management among architects and builders in FCT Abuja. Two research questions guided the study. A descriptive survey design was used for the study. The targeted population of the study was 312 respondents comprising of 148 registered architects and 164 registered builders in FCT Abuja. A 24 items structured questionnaire validated by three experts was used for data collection. To establish reliability, a pilot test was conducted in Minna, Niger State, involving six builders and four contractors. Using Cronbach's Alpha statistical technique, the overall reliability coefficient of the instrument was found to be 0.86. Data collected were coded and analyzed using the Statistical Package for Social Sciences (SPSS, Version 27). Mean and standard deviation were employed to answer the research questions. The findings of the study revealed that architects and builders in FCT Abuja are slightly aware of AI tools for building project management with a grand mean ($\bar{X} = 2.28$). The findings also revealed that the extent of adoption of AI tools for building project management among architects and builders in FCT Abuja was low with a grand mean ($\bar{X} = 1.73$). Based on the findings, it was recommended among others that professional development programmes, workshops and seminars should be organized for architects and builders in FCT Abuja to increase their awareness and understanding of AI tools and that construction firms, professional bodies and government agencies should provide the necessary infrastructure, technical support, and incentives to encourage the adoption of AI technologies.

Keywords: Awareness, Adoption, Artificial Intelligence Tools, Building Project Management, Architects, Builders

Introduction

Artificial Intelligence (AI) refers to computer systems or technologies designed to perform tasks that typically require human intelligence, such as learning, reasoning, problem-solving, decision-making, and pattern recognition. AI encompasses a range of technologies, including machine learning, natural language processing, expert systems, and computer vision, which enable machines to analyze large data sets, generate predictions, and automate complex processes (Russell & Norvig, 2021). In recent years, AI has gained widespread adoption across industries such as healthcare, finance, manufacturing, and education due to its ability to improve efficiency, accuracy, and productivity.

Building project management, on the other hand, is the process of planning, coordinating, and controlling construction projects from inception to completion within specified cost, time, and quality parameters (Kerzner, 2017). It requires the integration of diverse professional inputs from

architects, builders, engineers, and other stakeholders to achieve successful project delivery. In this context, AI tools are increasingly being applied to project management tasks such as scheduling, cost estimation, design optimization, risk analysis, resource allocation, and progress tracking (Wunderbuild, 2025; Cheche, *et al*, 2024). For instance, AI-powered Building Information Modeling (BIM) systems, generative design platforms, and predictive analytics tools are now being used to enhance decision-making, reduce delays, and minimize cost overruns in construction projects worldwide. The construction sector in Nigeria, plays a critical role in economic growth and infrastructure development. However, it faces persistent challenges such as cost overruns, delays, low productivity, and limited adoption of modern technologies (Owolabi *et al.*, 2022).

The integration of AI tools into building project management has the potential to address some of these challenges by improving efficiency, transparency, and collaboration among professionals. Studies have shown that many construction professionals in Nigeria are aware of AI applications in areas such as BIM, scheduling, and cost management, yet the actual level of adoption remains low due to factors like high cost of technology, lack of technical skills, resistance to change, and infrastructural limitations (Cheche, *et al*, 2024; Akwaowo, *et al.*, 2024). Despite the growing global evidence of AI's transformative potential, there is limited empirical research focusing on the level of awareness and extent of adoption of AI tools among specific professional groups in building construction industry in Nigeria. In FCT Abuja, which serves as a hub for architectural and building practices, the integration of AI into project management appears to be underexplored. Determining how aware architects and builders are of AI tools, and to what extent they adopt them, was crucial for guiding training, professional development, and policy interventions. This study therefore sought to determine the level of awareness and extent of adoption of AI tools for building project management among architects and builders in FCT Abuja.

Statement of the Problem

Building project management is expected to ensure that construction projects are delivered within stipulated time, cost, and quality standards. The integration of advanced technologies such as AI tools has the potential to make this possible by automating scheduling, enhancing cost estimation, predicting risks, and improving coordination among project stakeholders (Russell & Norvig, 2021; Kerzner, 2017). Across the globe, AI-enabled Building Information Modeling (BIM), predictive analytics, and automated monitoring systems are increasingly being applied to improve efficiency, minimize errors, and support data-driven decision-making in project management (Wunderbuild, 2025).

However, building project management in Nigeria continues to face persistent challenges such as delays, cost overruns, and inefficient resource utilization (Owolabi *et al.*, 2022). Although professionals are becoming increasingly aware of AI and its applications, the extent of adoption in project management remains very limited. Factors such as high implementation costs, inadequate technical expertise, poor digital infrastructure, and resistance to organizational change have slowed the uptake of AI technologies within the construction industry (Cheche *et al.*, 2024; Akwaowo *et al.*, 2024). As a result, many building projects in the FCT Abuja still depend largely on traditional project management methods, which are often less effective in handling the growing complexity of modern construction projects. This continued reliance undermines the ability of professionals to deliver projects in an efficient, competitive, and sustainable manner. Against this backdrop, the

present study sought to determine the level of awareness and extent of adoption of AI tools for building project management among architects and builders in FCT Abuja.

Aim and Objectives of the Study

The aim of the study is to determine the level of awareness and extent of adoption of artificial intelligence tools for building project management among architects and builders in FCT, Abuja, Nigeria. Specifically, the objectives are to determine:

1. the level of awareness of AI tools for building project management among architects and builders in FCT Abuja
2. the extent of adoption of AI tools for building project management among architects and builders in FCT Abuja

Research Questions

The following research questions were raised to guide the study:

1. What is the level of awareness of AI tools for building project management among architects and builders in FCT Abuja?
2. What is the extent of adoption of AI tools for building project management among architects and builders in FCT Abuja?

Methodology

A descriptive survey research design was adopted for this study. This design was considered appropriate because it allows for the systematic collection of data from a defined population through the use of structured questionnaires, thereby enabling the researcher to describe, analyze, and generalize findings to the larger population (Fraenkel *et al.*, 2019). The targeted population of the study was 312 respondents comprising of 148 registered architects and 164 registered builders in FCT Abuja. The instrument for data collection was a structured questionnaire titled: “*Awareness and Adoption of Artificial Intelligence Tools for Building Project Management Questionnaire (AAAITBPMQ)*”, developed by the researcher. The instrument contained 24 items and was structured on a four-point rating scale of: Highly Aware (HA = 4), Moderately Aware (MA = 3), Slightly Aware (SA = 2) and Not Aware (NA = 1) for research question one and Very High Extent (VHE = 4), High Extent (HE = 3), Moderate Extent (ME = 2) and Low Extent (LE = 1) for research question two. The instrument was subjected to face validation by three experts in the Department of Industrial and Technology Education, Federal University of Technology, Minna, Niger State. To establish reliability, a pilot test was conducted in Minna, Niger State, involving six builders and four contractors. The internal consistency of the instrument was determined using Cronbach’s Alpha, which yielded coefficients of 0.83 and 0.81 for the two sections, respectively. The overall reliability coefficient of 0.86 confirmed that the instrument was both reliable and suitable for use. The questionnaires were administered by the researcher with the support of trained research assistants through direct delivery and retrieval methods to ensure a high response rate. Data collected were coded and analyzed using the Statistical Package for the Social Sciences (SPSS, Version 27). Mean and standard deviation were employed to answer the research questions.

Research Question 1: What is the level of awareness of AI tools for building project management among architects and builders in FCT Abuja?

The data for answering research question one is presented in Table 1.

Table 1: Mean and Standard Deviation of Respondents on the Level of Awareness of AI Tools for Building Project Management

S/N	Items	Mean ($\bar{x}$)	SD	Remark
		(N = 312)		
1	I am aware of AI-enabled BIM for project design coordination.	3.63	0.44	HA
2	I am aware of AI tools used for project scheduling and time management optimization	2.32	0.65	MA
3	I am aware of AI applications that support cost estimation and budget control in projects	2.65	0.55	MA
4	I am aware of AI-driven predictive analytics for risk identification and management	1.40	0.79	NA
5	I am aware of AI applications for construction site monitoring and safety management	3.08	0.59	MA
6	I am aware of AI-powered tools for resource allocation and optimization in building projects	2.42	0.72	SA
7	I am aware of AI technologies used for quality control and defect detection during construction	1.39	0.53	NA
8	I am aware of AI-supported tools for decision-making in procurement and contract management.	2.48	0.64	SA
9	I am aware of AI applications in facility management and maintenance planning.	2.22	0.48	SA
10	I am aware of AI tools for generating project progress reports and performance analytics	2.17	0.50	SA
11	I am aware of AI-driven chatbots and virtual assistants for communication with stakeholders.	2.19	0.58	SA
12	I am aware of AI tools used for real-time tracking of materials and logistics	1.37	0.44	NA
Grand Mean/SD		2.28	0.58	Slightly Aware

Keys: N = Number of Respondents; SD = Standard Deviation; HA = High Aware, MA = Moderately Aware, SA =Slightly Aware; NA = Not Aware

The analysis in **Table 1** shows the mean and standard deviation of responses of the respondents on 12 items posed to determine the level of awareness of AI tools for building project management among architects and builders in FCT Abuja. A grand mean of **2.22** was obtained, indicating that the respondents jointly agreed that the level of awareness of AI tools is generally **slight**. The mean values of the items ranged between **1.37 - 3.08**, which fall within the categories of “Not Aware,” “Slightly Aware,” and “Moderately Aware.” This implies that while respondents demonstrated moderate awareness of AI applications such as BIM, project scheduling, cost estimation, and construction site safety management, they showed low awareness of advanced applications such as predictive analytics, real-time logistics tracking, and defect detection. The standard deviation of the items ranged from **0.44 - 0.79**, which are less than 1.96. This shows that the respondents were relatively close to one another in their responses, suggesting a high level of agreement and consistency in their views about their awareness of AI tools for building project management.

Research Question 2: What is the extent of adoption of AI tools for building project management among architects and builders in FCT Abuja?

The data for answering research question two is presented in Table 2.

Table 2: Mean and Standard Deviation of Respondents on the Extent of Adoption of AI Tools for Building Project Management

S/N	Items	Mean ($\bar{x}$)	SD	Remark
		(N = 312)		
1	I adopt AI-enabled BIM in the design and coordination of project	3.51	0.50	HE
2	I use AI tools for project scheduling and optimization of time management	1.40	0.60	LE
3	I adopt AI applications for cost estimation and budgetary control in building projects	2.47	0.68	ME
4	I apply AI-driven predictive analytics for risk management in construction projects	1.32	0.59	LE
5	I adopt AI-based tools for construction site monitoring and safety management.	1.45	0.65	LE
6	I utilize AI-powered tools for effective allocation and optimization of project resources	1.30	0.76	LE
7	I use AI applications for defect detection and quality control during construction	1.40	0.70	LE
8	I adopt AI-supported decision-making tools in procurement and contract management	1.47	0.63	LE
9	I use AI applications in facility management and long-term maintenance planning	1.42	0.72	LE
10	I apply AI tools for generating project progress reports and performance analytics.	2.40	0.49	ME
11	I adopt AI-driven chatbots or virtual assistants to enhance stakeholder communication	1.29	0.57	LE
12	I use AI for real-time monitoring of logistics and materials tracking	1.27	0.70	LE
Grand Mean/SD		1.73	0.63	Low Extent

Keys: N = Number of Respondents; SD = Standard Deviation; HE = High Extent; ME = Moderate Extent; LE = **Low Extent**

The analysis in Table 2 shows the mean and standard deviation of responses of the respondents on 12 items posed to determine the extent of adoption of AI tools for building project management among architects and builders in FCT Abuja. A grand mean of **1.73** was obtained, indicating that the respondents jointly agreed that the extent of adoption of AI tools is generally low. The mean values of the items ranged between **1.27 - 3.51**, which fall within the categories of Low Extent, Moderate Extent, and High Extent. This implies that although respondents demonstrated high adoption of AI-enabled BIM, and moderate adoption of AI tools for cost estimation and project reporting, the majority of other AI applications such as predictive analytics, project scheduling, safety monitoring, resource optimization, quality control, logistics tracking, and stakeholder communication recorded low levels of adoption. The standard deviation of the items ranged from **0.49 - 0.76**, which are less than 1.96. This shows that the respondents were relatively close to one

another in their responses, suggesting a high level of agreement and consistency in their views about the extent of adoption of AI tools for building project management.

Discussion of Findings

The findings of research question one revealed that architects and builders in FCT Abuja are slightly aware of AI tools for building project management. This implies that construction professionals in the sampled area have only limited knowledge of the potential applications of AI in managing building projects. Specifically, the respondents demonstrated awareness of AI tools in areas such as BIM, cost estimation, project scheduling, and report generation. However, their awareness of advanced applications such as predictive analytics for risk management, AI-driven logistics tracking, defect detection, and quality control was generally low. This slight level of awareness suggests that while some professionals are familiar with basic or commonly discussed AI applications, a significant knowledge gap exists regarding the broader and more sophisticated uses of AI that can transform project management. It also indicates that, within the context of the FCT Abuja construction industry, architects and builders are only beginning to encounter technological innovations and may not yet be fully exposed to the full range of AI tools available for project delivery.

The finding aligns with previous studies on AI adoption in construction management. Cheche *et al.* (2024) reported that Nigerian construction professionals exhibited minimal awareness of advanced AI technologies due to limited exposure, inadequate sensitization, and insufficient training opportunities. Similarly, Akwaowo *et al.* (2024) observed that although BIM is increasingly recognized in the Nigerian built environment, awareness of AI-driven risk management, real-time monitoring, and logistics tools remains very low. On the global scale, however, studies such as Kerzner (2017) and Russell and Norvig (2021) indicate growing awareness and recognition of AI tools among construction professionals, in technologically advanced countries. The finding implies that the major barriers to awareness are not professional resistance but rather inadequate exposure, lack of structured training, and limited institutional support.

The findings of research question two revealed that the extent of adoption of AI tools for building project management among architects and builders in FCT Abuja is **low**. This implies that despite some degree of awareness, construction professionals in the area have not substantially incorporated AI into their project management practices. Specifically, adoption was evident in basic applications such as Building Information Modeling (BIM) and project reporting, but the use of advanced AI-driven tools for predictive analytics, logistics tracking, defect detection, and real-time monitoring was found to be very minimal. This low level of adoption suggests that while architects and builders may recognize the existence of AI tools, they face significant challenges in translating awareness into actual usage. It further indicates that within the FCT Abuja construction sector, barriers such as high implementation costs, inadequate training, lack of organizational support, and infrastructural limitations hinder the integration of AI into everyday project management practices.

The finding is consistent with previous studies in the Nigerian construction industry. Afolabi *et al.* (2021) observed that construction professionals often lag in adopting innovative digital tools due to insufficient exposure and institutional constraints. Similarly, Akwaowo *et al.* (2024) noted that

while BIM is slowly gaining ground, broader AI applications in cost control, quality assurance, and risk management remain largely underutilized in Nigeria. By contrast, international studies such as Abioye *et al.* (2021) and Kerzner (2017) reported higher levels of AI adoption in advanced economies, where enabling policies, infrastructure, and training opportunities are more widely available. In the present study, the low extent of adoption among architects and builders in FCT Abuja implies that despite emerging awareness, the sector is not yet prepared to fully harness the benefits of AI for improved project delivery.

Conclusion

The study revealed that architects and builders in FCT Abuja have only a slight awareness and a low extent of adoption of AI tools for building project management. This indicates that, although professionals recognize some potential applications of AI, its practical use in project delivery remains very limited. The findings suggest that deliberate efforts in training, institutional support, and infrastructure development are needed to enhance awareness and promote the adoption of AI in the construction industry for improved efficiency and competitiveness.

Recommendations

The following recommendations were made based on the findings of the study:

1. Professional development programmes, workshops, and seminars should be organized for architects and builders in FCT Abuja to increase their awareness and understanding of AI tools
2. Construction firms, professional bodies and government agencies should provide the necessary infrastructure, technical support, and incentives to encourage the adoption of AI technologies.

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MAXIMISING BIOLOGY LEARNING OUTCOMES THROUGH WHATSAPP-BASED E-LEARNING: OPPORTUNITIES AND CHALLENGES

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Abstract

The integration of WhatsApp into education has emerged as a significant innovation for enhancing teaching and learning outcomes. This study reviews empirical works conducted between 2021 and 2025, focusing on the application of WhatsApp in diverse educational contexts with particular relevance to Biology instruction. The reviewed studies reveal that WhatsApp promotes collaboration, engagement and accessibility while supporting teachers in facilitating interactive learning. Evidence indicates that its use strengthens communication, builds learning communities and fosters active student participation, though challenges such as distraction, inconsistent participation and technological limitations remain. The findings underscore that WhatsApp-based learning can enhance academic outcomes when aligned with structured modules and supported by teacher training. The study concludes by recommending curriculum integration, collaborative development and continuous monitoring of WhatsApp learning environments, while emphasizing the importance of long-term empirical research to validate sustainability and scalability in Biology education.

Keywords: Accessibility, Biology outcomes, Curriculum alignment, Engagement, Teacher training, WhatsApp-based learning

Introduction

Teaching Biology in senior secondary schools is often undermined by structural and pedagogical challenges that restrict meaningful learning. Abdusseminu (2022) notes that limited laboratory facilities and reliance on traditional lecture methods leave students unable to connect theory with practice. This problem resonates with Gallagher and Savage's (2023) review of challenge-based learning, which stresses that students engage more deeply when instruction moves beyond memorisation to promote active problem-solving. Yet, many classrooms still favour teacher-dominated approaches, preventing learners from exploring scientific ideas independently. This persistent gap underscores the need for innovative, student-centred strategies that can revitalise Biology teaching and learning.

Mobile learning has emerged as a practical response to these educational challenges, particularly in settings where resources are scarce. Guillaume *et al.* (2022) highlight the effectiveness of mobile-social learning for professional development in low- and middle-income countries, showing its ability to extend access and foster collaborative learning. Similarly, Chisholm *et al.* (2024) demonstrated how WhatsApp-based microlearning supported rural healthcare workers, proving that simple tools can deliver impactful instruction even in difficult contexts. These findings suggest that mobile platforms, especially WhatsApp, can transform secondary school Biology learning by enabling interaction, flexibility and continuity beyond the classroom walls.

WhatsApp provides a promising platform for enhancing Biology education in Nigerian schools. Estrella (2024) illustrates its academic potential by showing how WhatsApp improved essay writing among Ecuadorian undergraduates, confirming its adaptability across disciplines. In parallel, Arifin *et al.* (2024) emphasise the importance of integrating digital tools to strengthen 21st-century skills, particularly in post-pandemic education. Drawing from these insights, this paper positions WhatsApp as more than a messaging app; it is a low-cost, scalable learning environment. By embedding structured modules and teacher guidance, WhatsApp-based e-learning can foster collaboration, autonomy and improved outcomes for Biology students.

WhatsApp Platform Accessibility and Student Interaction

Accessibility and Engagement

WhatsApp has become a widely accessible platform, particularly in educational contexts where students may lack access to expensive learning technologies. Shahzad (2024) observes that its ubiquity makes it a natural medium for both communication and knowledge sharing, reducing barriers that often exclude learners. In higher education, Enakrire and Kehinde (2022) noted that WhatsApp supports teaching and learning by connecting students and teachers through familiar, low-cost channels. For secondary school Biology, this accessibility means learners can participate in academic discussions with little technical training, creating inclusive opportunities that traditional classroom settings sometimes struggle to provide.

Beyond mere access, WhatsApp also fosters meaningful peer interaction and collaboration, enabling students to exchange ideas more actively. Cronje and Van Zyl (2022) demonstrated how WhatsApp builds learning communities, strengthening trust and shared responsibility among learners. Similarly, Estrada Molina (2022) found that WhatsApp significantly boosts student engagement when used to facilitate group tasks and discussions. In the Biology classroom, this translates into students questioning, debating and problem-solving collectively in real time. By blending informal social interactions with structured academic exchanges, WhatsApp helps learners engage more deeply, bridging the gap between everyday communication and formal study.

Learner Autonomy and Continuous Learning

A notable strength of WhatsApp is its ability to support self-paced learning, allowing students to revisit materials on their own terms. Romero-Saritama *et al.* (2025) found that WhatsApp use in distance education enhanced academic interaction by giving learners the freedom to participate asynchronously. This autonomy is particularly valuable in resource-limited environments, where students may not have continuous internet access. Holly *et al.* (2023) also reported that students using WhatsApp showed increased interest in learning, partly because the platform enables them to take charge of their study schedule, reviewing concepts whenever they choose.

Another important aspect is the immediate access to materials and feedback that WhatsApp provides. Teachers can upload notes, videos, or quizzes, while learners can instantly ask clarifying questions or share solutions with peers. Naghdipour and Manca (2023) highlight that WhatsApp enhances “teaching presence,” ensuring learners feel supported and guided even outside traditional classrooms. Quick responses from both teachers and peers reduce delays in problem-solving and sustain motivation. For Biology instruction, where complex topics often require step-by-step

clarification, this immediacy strengthens comprehension and builds learner confidence, reinforcing continuous engagement beyond school hours.

Pedagogical and Practical Implications

The integration of WhatsApp into teaching practice offers valuable opportunities to supplement traditional classroom methods rather than replace them. Romero-Saritama *et al.* (2025) suggest that WhatsApp's affordances make it an effective complement to face-to-face instruction, particularly when students need reinforcement after lessons. Enakrire and Kehinde (2022) echo this, arguing that WhatsApp's role in education lies in extending learning beyond physical classrooms. In senior secondary Biology, WhatsApp can act as a revision hub, where diagrams, practical activities and quizzes are shared to reinforce what was taught, ensuring learning continues seamlessly after school hours.

WhatsApp also supports innovative methods such as flipped classrooms and blended learning models, aligning well with 21st-century educational reforms. Estrada Molina (2022) showed how WhatsApp increased engagement when integrated into flipped learning environments, as students interacted with materials before class and arrived prepared for deeper discussions. Cronje and Van Zyl (2022) similarly highlight how WhatsApp communities promote active collaboration, mirroring principles of blended learning. For Biology teachers, this means students could study a video or resource at home and then use classroom time for practical demonstrations and inquiry-based learning, ultimately enriching the teaching learning process.

Challenges

Network Limitations and Connectivity Issues

Unstable internet connections, high data costs and inconsistent access to mobile devices hinder equitable participation, making it difficult for all learners to fully benefit from WhatsApp-based learning.

Teacher Preparedness

Many teachers lack adequate training in digital pedagogy, limiting their ability to design engaging content and moderate WhatsApp learning groups effectively, thereby reducing the platform's potential for meaningful Biology instruction.

Potential Distractions and Content Management

Because WhatsApp is primarily a social platform, students may become distracted by non-academic messages, while teachers struggle to manage content flow, creating challenges in maintaining academic focus and discipline.

4. Review of Studies on WhatsApp for Learning

Author(s) and Location / Area of Research			Result / Findings
Year	Study	Methodology / Sample	
Conde <i>et al.</i> (2021)	International (Human-Computer	Comparative study of WhatsApp vs Telegram in teamwork interaction	WhatsApp encouraged quicker interaction, while Telegram offered

Author(s) and Location / Area of Research		Methodology / Sample	Result / Findings
Year	Study		
	Interaction Conference)		better file handling; both had distinct strengths for collaboration.
Bonsu <i>et al.</i> (2021)	Ghana	Survey during COVID-19, university students	Students initially accepted WhatsApp as a learning tool due to accessibility and familiarity, though challenges of distraction and network issues remained.
Enakrire and Kehinde (2022)	Nigeria	Case analysis of higher education institutions	WhatsApp supported teaching and learning, promoting continuous communication between lecturers and students beyond the classroom.
Cronje and Van Zyl (2022)	South Africa	Qualitative study on building learning communities	WhatsApp facilitated community building, collaboration and peer support, improving the sense of belonging among learners.
Estrada Molina (2022)	International	Mixed-methods approach with students	WhatsApp and Telegram improved engagement, with WhatsApp showing stronger impact on real-time student collaboration.
Van den Berg and Mudau (2022)	South Africa	Survey of postgraduate students during COVID-19	WhatsApp groups supported online communication and learning continuity during disruptions, though academic focus needed regulation.
Naghdipour and Manca (2023)	International	Study of language learning groups	WhatsApp enhanced teaching presence, fostering interaction and feedback among students.
Holly <i>et al.</i> (2023)	Indonesia	Experimental study on students	WhatsApp increased learning interest and motivation when integrated into lessons.
Yaumi <i>et al.</i> (2023)	Indonesia	Semiotic technology analysis	WhatsApp supported teaching and learning during COVID-19 and post-pandemic era, highlighting symbolic and functional roles.

Author(s) and Location / Area of Research		Result / Findings	
Year	Study	Methodology / Sample	
Estrella (2024)	Ecuador	Study on undergraduates using WhatsApp for essay writing	WhatsApp improved academic writing skills, enabling collaborative peer learning.
Chisholm <i>et al.</i> (2024)	South Africa	Mixed methods, cluster-randomised study protocol	Designed WhatsApp microlearning for healthcare workers; expected to strengthen knowledge sharing and accessibility in rural areas.
Shahzad (2024)	Pakistan	Analytical study on WhatsApp as a social medium	WhatsApp emerged as a strong platform for academic and social interaction, blending formal and informal learning.
Nsirim <i>et al.</i> (2024)	Nigeria	Case of WhatsApp's new screen-sharing feature	Screen sharing broadened the instructional capacity of WhatsApp in higher education, making virtual teaching more interactive.
Romero-Saritama <i>et al.</i> (2025)	Ecuador	Distance education study	WhatsApp increased academic interaction, though student motivation was influenced by institutional and contextual factors.
Adekunle (2025)	Nigeria (University of Ibadan)	Comparative study of Google Classroom vs WhatsApp in ODL	WhatsApp proved more engaging and accessible than Google Classroom, though limited in advanced learning management features.

Conclusion

WhatsApp-based e-learning holds strong potential to enhance learning outcomes in Biology by providing accessible, interactive and flexible opportunities for students to engage with content beyond the classroom. Its ability to support peer collaboration, foster learner autonomy and create continuous learning spaces makes it a valuable complement to traditional teaching. Nonetheless, successful adoption requires careful planning, adequate teacher training and strategies to minimise distractions and connectivity challenges. Further empirical research is needed to establish its long-term impact and scalability, but with thoughtful implementation, WhatsApp can significantly contribute to more engaging and effective Biology education.

Recommendations

1. Teachers should receive comprehensive training programmes to effectively integrate WhatsApp-based e-learning into Biology instruction.
2. Curriculum-aligned modules must be carefully structured to ensure content relevance and maximise student learning outcomes.
3. Schools should establish monitoring systems that track and support students' engagement in WhatsApp learning communities.
4. Strong collaboration is needed between educators and developers to design user-friendly, pedagogically sound WhatsApp learning resources.
5. Long-term empirical studies should be conducted to assess sustainability, effectiveness and scalability of WhatsApp-based Biology instruction.

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TEXT-TO-SPEECH SOFTWARE AS A CATALYST FOR IMPROVING ENGLISH PRONUNCIATION: PERSPECTIVES ON TEXTALOUD AND BALABOLKA IN SECONDARY EDUCATION

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Abstract

Pronunciation is a critical aspect of English language learning, yet it remains largely underemphasized in many secondary school classrooms, leading to limited oral competence among learners. This opinion paper explores the potential of TextAloud and Balabolka two text-to-speech (TTS) applications in enhancing students' pronunciation skills. Drawing on existing literature, the paper highlights TextAloud's natural-sounding voices and prosodic modelling as strengths for quality pronunciation practice, while Balabolka offers free, accessible and customisable options suitable for resource-limited settings. Both tools can complement teacher-led instruction, supporting learner autonomy, motivation and consistent practice. The paper also considers challenges, including teacher training gaps, infrastructure limitations and risks of overreliance on technology. It concludes by advocating for strategic integration of TTS tools in classrooms and calls for long-term empirical studies to validate their effectiveness in improving pronunciation outcomes.

Keywords: Accessibility, Balabolka, English pronunciation, Learner autonomy, Text-to-Speech (TTS) and TextAloud

Introduction

English pronunciation occupies a central place in communication and academic success, yet it continues to be one of the weakest aspects of language learning among Nigerian students. Muhammad, Ya'u *et al.* (2018) emphasise that effective command of spoken English is essential not only for classroom achievement but also for participation in wider society. Unfortunately, pronunciation is often overshadowed by grammar and vocabulary instruction, leaving learners with limited oral competence. The situation is worsened by the lack of specialised training for teachers, many of whom struggle to model accurate sounds and stress patterns for their students.

The realities in Nigerian secondary schools further compound these challenges. Murana and Muniru (2019) observe that overcrowded classrooms, poorly resourced language laboratories and insufficient teaching aids constrain meaningful pronunciation practice. In such settings, learners rarely receive the individualised attention required to correct errors or develop confidence in speaking. This limitation often results in students leaving school with weak intelligibility, affecting both examination performance and self-expression. Addressing this persistent problem requires innovative approaches that go beyond the traditional chalk-and-talk method and that make room for learner-centred practice and technological support.

In recent years, digital tools have become increasingly relevant in addressing gaps in language teaching. Ukoha *et al.* (2024) highlight the positive perceptions teachers and learners hold towards technology-enhanced instruction, noting that digital applications can stimulate engagement and

broaden access to quality input. Similarly, Sulaiman *et al.* (2025) demonstrate that text-to-speech (TTS) technology improved reading habits among university students, suggesting its potential for pronunciation learning at the secondary school level. Within this context, TextAloud and Balabolka stand out as tools that could offer scalable, accessible solutions. This paper therefore argues that TTS software, when integrated with classroom practices, can bridge the gap between theory and authentic spoken English.

Conceptual Background

English Pronunciation and Learning Challenges

Pronunciation in English learning extends beyond the accurate articulation of sounds to include mastery of segmental features such as vowels and consonants and suprasegmental features like stress, intonation, pitch and rhythm, which shape meaning and intelligibility. Ahmed (2022) underscores how these suprasegmental elements often determine the naturalness of speech, yet they remain difficult for many learners to acquire. Similarly, Umar and Aspany (2024) reveal that students commonly struggle with both segmental clarity and suprasegmental fluency, limiting their overall communicative competence. Boutheyna and Oumayma (2024) further highlight that such challenges persist because traditional classroom approaches rarely provide sufficient practice or corrective feedback.

Text-to-Speech (TTS) Technology in Education

Text-to-Speech (TTS) technology refers to computer-based systems that convert written text into spoken output, offering learners consistent and repeatable models of pronunciation. In language learning, TTS has been applied to enhance listening, reading fluency and oral practice. Fitria (2022) demonstrated the effectiveness of text-to-speech software in supporting pronunciation teaching, showing how digital voices can provide learners with accessible models outside the classroom. Taylor (2022) discusses the capacity of advanced TTS synthesis to produce natural prosody, making speech modelling more authentic. Similarly, Saadia (2023) found TTS effective in improving learners' pronunciation of English past tense endings, reinforcing its pedagogical potential.

Perspectives on TextAloud and Balabolka

TextAloud

TextAloud has emerged as a valuable text-to-speech application that supports language learning by providing synthetic yet increasingly natural voices for reading written text aloud. Roslaini and Komara (2020) show that the software can significantly aid pronunciation teaching, as it offers learners repeated exposure to word stress, rhythm and intonation patterns often missed in teacher-led instruction. With multi-voice options and both online and offline accessibility, TextAloud creates opportunities for learners to practise listening and imitation at their own pace. Fitria (2022) further emphasises that TTS tools like TextAloud enrich classroom engagement by modelling pronunciation in ways that are consistent and reliable.

Despite its advantages, TextAloud is not without limitations. Some versions require internet access for premium voices, while costs can limit accessibility for schools in resource-constrained contexts. Moreover, Roberts *et al.* (2024) note that reading text aloud improves memory retention but does not necessarily guarantee deeper comprehension, which raises questions about overreliance on TTS tools for holistic language learning. Thus, while TextAloud provides learners

with valuable auditory reinforcement for pronunciation, it should be viewed as a complementary resource rather than a stand-alone solution. Its real strength lies in supplementing teacher input and offering individualised practice beyond the classroom.

Balabolka

Balabolka stands out as one of the most accessible text-to-speech applications because it is completely free and lightweight, making it especially attractive for schools with limited resources. It supports multiple languages and allows users to customize settings such as voice speed, pitch and pronunciation, which can be adapted to suit different learning needs. Amelia (2017) demonstrated its usefulness in teaching listening, showing that the software helps learners familiarize themselves with authentic-sounding input. Similarly, andipurnama *et al.* (2022) found Balabolka valuable for visually impaired students, as it improved their ability to access electronic learning resources with greater independence.

Despite these strengths, Balabolka does have limitations. The voices, while functional, are often less natural-sounding than those offered by commercial software, which may reduce the authenticity of pronunciation models. Sylvia (2024) notes that additional configurations, such as installing voice engines, are sometimes required to optimise the experience, which can present a barrier for users with limited technical skills. Nevertheless, Balabolka remains a powerful option for learners and institutions seeking an affordable and adaptable tool. Its true advantage lies in democratising access to pronunciation practice, ensuring that even students in under-resourced contexts can benefit from repeated exposure to spoken English.

Comparative Reflections

Feature/Aspect	TextAloud (Quality)	Balabolka (Accessibility)
Cost	Paid software, premium features require purchase	Completely free, open-access
Voice Quality	More natural-sounding, offers multi-voice options	Less natural, depends on installed voice engines
Customisation	Adjustable speed, pitch, intonation, with offline/online use	Highly customisable, supports multiple languages and formats
Accessibility	May require internet for premium voices	Lightweight, works well on low-resource devices
Suitability for Schools	Best for well-resourced institutions seeking quality models	Ideal for resource-limited schools needing affordable tools
Pedagogical Role	Reinforces stress, rhythm and intonation modelling	Provides basic pronunciation and listening support

Reflection: Both tools can complement teacher-led pronunciation instruction—TextAloud offers higher quality models, while Balabolka ensures inclusive access in resource-constrained settings.

Review of Studies on Balabolka and TextAloud

Author(s) and Year	Location/Area of Study	Methodology / Sample	Result / Findings
Balabolka			
Amelia (2017)	Solok, Indonesia	Classroom-based study on teaching listening using Balabolka	Balabolka enhanced students' listening comprehension by providing repeated exposure to audio models.
Pramono (2022)	Indonesia	Quasi-experimental design with secondary school students learning procedural text	Use of Balabolka improved students' speaking skills and confidence in delivering procedural texts.
Andipurnama <i>et al.</i> (2022)	Indonesia	Intervention with visually impaired students	Balabolka improved access to electronic resources, supporting independent learning for visually impaired learners.
Lawa <i>et al.</i> (2025)	Indonesia (SMP Negeri 1 Pandawai)	Quantitative study with Class VII students (Phase D)	Balabolka significantly increased learners' motivation to study by making content more engaging.
Sylvia (2024)	Online review (global perspective)	Software evaluation and review	Balabolka identified as one of the best free TTS software, though limited by less natural-sounding voices.
TextAloud			
Roslaini and Komara (2020)	Indonesia	Classroom-based research on pronunciation teaching	TextAloud improved students' pronunciation through repeated listening and practice with stress and intonation.
Al-Jarf (2022)	Saudi Arabia	Experimental study with EFL freshman students	Text-to-speech software improved decoding skills and pronunciation accuracy among learners.
Fitria (2022)	Indonesia	Case study on TTS (Natural Reader/TextAloud equivalent) in pronunciation teaching	Found that TTS enriched classroom practice by offering consistent and reliable pronunciation models.
Roberts <i>et al.</i> (2024)	Canada	Experimental psychology study with undergraduate students	Reading text aloud enhanced memory retention but had little effect on comprehension.

Pedagogical Implications

Text-to-Speech (TTS) applications such as Balabolka and TextAloud offer rich opportunities for both teachers and learners in English language education (Amelia (2017; Roslaini and Komara 2020). For teachers, these tools provide additional support in demonstrating pronunciation, rhythm and intonation beyond their own voice. This expands instructional reach, especially in large classes where personalised modelling is difficult. For learners, TTS can serve as a practice companion, enabling repeated listening and shadowing exercises at their own pace. Such integration bridges the gap between classroom demonstration and individual reinforcement, fostering consistency and accuracy in oral language learning.

Equally important is the way TTS encourages learner autonomy and motivation. By accessing digital voices independently, students gain greater control over their learning and can experiment without fear of embarrassment. This resonates with constructivist learning theory, which emphasises active knowledge construction and with multimedia learning theory, where multiple channels of input (visual text and auditory speech) strengthen comprehension and retention. In practice, teachers can adopt flexible integration models using TTS for supplementary drills, assigning it as homework for pronunciation reinforcement, or deploying it as remedial support for learners who need extra practice. In doing so, these tools become not replacements, but valuable complements to teacher-led instruction, extending learning opportunities beyond the classroom walls.

Challenges and Considerations

Teacher digital literacy and training gaps

Many teachers face limited digital literacy, which can hinder effective use of TTS tools. Without adequate training, software like Balabolka or TextAloud may remain underutilized. Professional development is crucial to equip educators with both the confidence and practical skills to integrate these resources meaningfully into language classrooms.

Risk of overreliance on technology

While TTS tools are valuable, excessive dependence may reduce opportunities for authentic human interaction in language learning. Students need balanced exposure listening to both digital and human voices. Teachers must therefore use these tools as complementary aids rather than substitutes, ensuring technology enhances rather than overshadows pedagogy.

Infrastructure issues (electricity, devices and internet access)

Schools in resource-limited contexts often struggle with unstable electricity, limited devices and weak internet connectivity. These challenges can restrict consistent access to TTS applications, reducing their effectiveness. Addressing infrastructure gaps through government investment and community support is essential if learners are to benefit fully from digital learning innovations.

Ensuring inclusivity and equal access

Not all learners have equal access to technology at home, which risks widening educational inequalities. Inclusive strategies such as providing shared devices, offline functionality and school-based access can help bridge the digital divide. By prioritising fairness, educators ensure that TTS tools support every learner rather than reinforcing existing barriers.

Conclusion

Pronunciation remains a central component of English language learning, yet it is often neglected in classroom practice, leaving many students with limited oral competence. Text-to-Speech tools such as TextAloud and Balabolka offer scalable and cost-effective support, providing learners with repeated, accessible models of stress, rhythm and intonation. However, these applications should complement rather than replace teacher-led instruction, reinforcing guidance and feedback in authentic learning contexts. To fully understand their long-term impact on pronunciation proficiency, retention and learner confidence, further empirical studies are essential, particularly in diverse classroom settings and resource-constrained environments.

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ARTIFICIAL INTELLIGENCE IN TECHNICAL AND VOCATIONAL EDUCATION AND TRAINING: ETHICAL DILEMMAS FOR SKILLS DEVELOPMENT IN NIGERIA

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Abstract

Artificial intelligence (AI) is reshaping education globally, with growing implications for Technical and Vocational Education and Training (TVET) in Nigeria. This paper examines how AI applications, ranging from adaptive learning and intelligent simulations to automated assessments and institutional management can strengthen skills training while also generating ethical dilemmas. Using a conceptual and theoretical lens, particularly the Technology Acceptance Model and Socio-Technical Systems Theory, the paper explores tensions around data privacy, equitable access, teacher roles, and accountability in AI-driven TVET. Findings highlight that although AI holds promise for workforce competitiveness, improved employability, and alignment with national development goals, unresolved ethical concerns and infrastructural deficits threaten inclusive and sustainable outcomes. The study recommends that the National Board for Technical Education, policymakers, and TVET institutions collaborate to establish ethical guidelines, strengthen teacher training, and reform curricula to embed digital and ethical literacy, ensuring that AI adoption enhances inclusive and sustainable skills development in Nigeria.

Keywords: Artificial Intelligence, TVET, Skills Development, Ethical Dilemmas, Nigeria

Introduction

Education today is being reshaped by digital technologies that improve access, quality, and personalization, with artificial intelligence (AI) standing out as the most transformative. AI can be understood as computer systems designed to perform tasks that normally require human intelligence, such as recognizing patterns, learning from experience, making decisions, and solving problems (Samuel, 2023). In practical terms, this involves tools like machine learning models, deep-learning networks, and generative systems that support adaptive tutoring, simulations, predictive analysis, and automated assessments. These functions are particularly valuable in vocational contexts, where learners benefit from personalized guidance, immediate feedback, and realistic practice environments (UNESCO, 2023; OECD, 2021). For this reason, AI is highly relevant to Technical and Vocational Education and Training.

Technical and Vocational Education and Training (TVET) comprises formal, non-formal and informal learning pathways that develop occupational competencies, hands-on technical skills, and workplace behaviours required for employment and entrepreneurship. TVET in Nigeria spans technical colleges, polytechnics, vocational enterprise institutions, and apprenticeship schemes, and is intended to link training with industry needs (Federal Ministry of Education, 2019; NBTE, 2025). Key aspects include competency-based curricula, workplace attachments, teacher–industry collaboration, and assessment for certification. However, persistent problems such as underfunding, obsolete equipment, weak industry linkages, low instructor capacity, and uneven

digital adoption constrain TVET's ability to deliver relevant outcomes (Ogunode & Abiodun, 2024; Nwanguma & Onyeukwu, 2024). Improving these elements is therefore central to effective skills development.

Skills development denotes the deliberate process of acquiring, enhancing, and certifying technical competencies and complementary soft skills (problem solving, communication, adaptability) that enable productive participation in labour markets and technological economies. Successful skills systems align curricula with employer needs, provide practical training opportunities, and ensure instructors are industry-competent; failure to do so results in graduate unemployment, skills mismatches, and lost productivity (ILO, 2022). Though AI-based tools can strengthen simulation training, individualized remediation, and competency-based assessment (Omeh *et al.*, 2024), their use also raises questions about transparency of assessment, and the professional role of teachers, tensions that together amount to an ethical dilemma.

The notion of an ethical dilemma captures situations where competing moral principles collide, such that meeting one obligation requires compromising another. In the context of TVET, the adoption of AI creates such conflicts, as the drive for efficiency and innovation must be weighed against concerns of equity, privacy, accountability, and the professional autonomy of teachers (Olukunle-Ajiye & Omokhabi, 2025). These tensions are not abstract but live and consequential for Nigeria's TVET reform agenda. National policy signals, including new ICT standards and moves to mainstream AI education, reveal strong public ambition to digitalize skills training (Federal Ministry of Education, 2019). Despite this, institutional readiness remains uneven, digital infrastructure is limited, and there is little empirical evidence on how ethical risks play out in TVET practice (Ogunode & Abiodun, 2024).

This study is justified by the urgent need to bridge the gap between policy ambition and operational safeguards in Nigeria's skills development sector. While government frameworks emphasize digital transformation, few context-sensitive models explain how AI can be integrated in ways that enhance skills outcomes while protecting equity, privacy, and professional integrity. Addressing this gap is critical for three reasons: it situates Nigeria within the global conversation on ethical AI in education, it responds to the lack of local evidence on how AI's ethical dilemmas affect TVET delivery, and it provides actionable strategies for policymakers, institutions, and practitioners.

Conceptual Framework

Artificial Intelligence and Skills Development

Artificial intelligence (AI) has increasingly been positioned as a catalyst for transforming how individuals acquire, refine, and apply skills in dynamic labor markets. In the education domain, AI functions as a tool for simulating real-world tasks, personalizing learning trajectories, and providing immediate, data-driven feedback (Balogun *et al.*, 2024; Peters & Olojede, 2025). Within TVET, these capacities are particularly significant because of its emphasis on practical competencies and employability. AI-powered platforms can deliver adaptive tutorials that match learners' pace, intelligent simulations that replicate industrial processes, and predictive analytics that identify training gaps before they impact workplace readiness (Omeh *et al.*, 2024). By aligning instruction more closely with occupational standards, AI promises to reduce skills mismatches, increase graduate employability, and support lifelong learning. However, the potential benefits depend on whether TVET institutions possess the infrastructure, trained personnel, and governance

frameworks to integrate AI effectively into teaching and assessment (Nwanguma & Onyeukwu, 2024).

Ethical Dimensions in TVET

While AI offers opportunities to enhance skills development, its integration also raises significant ethical considerations that must be addressed to ensure equitable and responsible use. Ethical dilemmas in Technical and Vocational Education and Training (TVET) often arise from conflicts between the adoption of innovative technologies and the equitable access to skills development, the pursuit of operational efficiency and the protection of learners' privacy, or the integration of automation and the professional autonomy of instructors (Apie, 2025; Afolabi, 2024). In Technical and Vocational Education and Training (TVET), these ethical concerns appear in multiple ways: algorithmic biases that may disadvantage certain groups of learners, vulnerabilities in data protection on digital training platforms, lack of transparency in automated assessments that can undermine trust in certification, and the transformation of instructors' roles in ways that could compromise their professional authority or job security (Olukunle-Ajiye & Omokhabi, 2025). These challenges highlight the critical need for ethical frameworks that balance technological innovation with human-centered values, ensuring that AI enhances rather than diminishes inclusive skills development. Conceptually, AI in TVET should therefore be viewed not merely as a tool for efficiency but as a socio-technical system whose implications for equity, transparency, and professional integrity are significant and demand careful governance.

Theoretical Framework

Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM), proposed by Fred Davis (1989), explains why individuals accept or reject new technologies. It is built on two main constructs: perceived usefulness (the belief that using a system will improve job performance) and perceived ease of use (the belief that using the system requires minimal effort). These two perceptions shape a user's attitude and intention toward technology adoption. Within the context of TVET, TAM is highly relevant for understanding how teachers, students, and administrators respond to AI applications such as adaptive tutors, simulation platforms, and automated assessments. If instructors believe AI enhances teaching effectiveness and students find it user-friendly, adoption is more likely. Conversely, without adequate training and institutional support, even powerful AI tools may face resistance (Samuel, 2023). Thus, TAM highlights that the success of AI in improving skills development depends not only on technological capability but also on user perceptions and organizational readiness.

Socio-Technical Systems Theory

The Socio-Technical Systems Theory, developed by Eric Trist and Ken Bamforth (1951), emphasizes that technological systems cannot be separated from the social systems in which they are embedded. The theory argues that effective innovation requires the joint optimization of the technical subsystem (tools, machines, processes) and the social subsystem (people, roles, norms, culture). Applying this to AI in TVET, the value of technologies such as intelligent simulations or predictive analytics depends on how they interact with teacher expertise, institutional structures, and student expectations (Nwanguma & Onyeukwu, 2024). For example, AI-based tools may enhance efficiency but could undermine learning if they disregard teachers' professional roles or learners' trust. This framework therefore stresses the need to align AI adoption with both

technological design and human-centered practices. By balancing the social and technical dimensions, TVET institutions can ensure AI contributes to sustainable and ethically responsible skills development.

AI Applications in TVET

Teaching and Learning Enhancement

Artificial intelligence offers powerful tools to enrich teaching and learning in TVET. Intelligent tutoring systems, adaptive learning platforms, and AI-driven learning management systems can personalize instruction to meet learners' diverse needs. These technologies adjust the pace and content of lessons based on student progress, thereby increasing engagement and reducing dropout rates (UNESCO, 2023). For TVET, where learners acquire practical and technical competencies, AI-supported platforms help deliver tailored guidance and reinforce critical problem-solving and innovation skills. Teachers also benefit from AI through automated lesson planning suggestions, digital resource curation, and predictive insights into learner difficulties, enabling them to focus more on mentorship and skill transfer.

Assessment and Certification

Assessment is central to vocational education, where competence must be demonstrated in measurable ways. AI facilitates automated and adaptive assessments that go beyond traditional testing by analyzing performance data in real time. For example, AI-powered assessment tools can evaluate practical skills through video analysis, voice recognition, or interaction with virtual machines (OECD, 2021). Certification systems can also integrate AI for secure credentialing using blockchain and biometric verification to reduce fraud. In this way, AI not only ensures reliability and fairness but also enables continuous assessment, providing learners with instant feedback and building a transparent record of competence.

Skills Training and Simulation

AI plays a transformative role in simulation-based learning, particularly vital in vocational and technical education. Through immersive technologies such as virtual reality (VR) and augmented reality (AR) combined with AI, learners can practice complex tasks in safe, controlled environments. For example, mechanics can simulate engine repairs, nurses can rehearse clinical procedures, and electricians can test wiring systems without safety risks (Samuel, 2023). These intelligent simulations replicate workplace scenarios with high fidelity, enabling learners to build competence, confidence, and creativity before engaging in real-world practice. Such applications align with the global drive for work-ready graduates in the 21st-century economy.

Administrative and Managerial Functions

Beyond the classroom, AI supports the administration and management of TVET institutions. Predictive analytics can forecast student enrollment trends, dropout risks, and labor market demands, thereby helping administrators align training programs with workforce needs (Nwanguma & Onyeukwu, 2024). AI-driven scheduling systems optimize timetables, resource allocation, and equipment use. Chatbots and virtual assistants enhance communication by responding to student inquiries and providing guidance on admission or career pathways. By reducing administrative burden, AI allows leaders and staff to devote more energy to instructional quality and institutional growth.

Ethical Dilemmas in AI-Driven TVET

Data Privacy and Security Concerns

AI systems in TVET collect and process large volumes of learner data, including performance records, biometric identifiers, and behavioral analytics. While this data enables personalized learning and targeted interventions, it also creates risks of unauthorized access, misuse, or breaches (OECD, 2021). In contexts with weak data protection frameworks, as in many Nigerian institutions, students' personal information may be exposed to exploitation or surveillance. This dilemma highlights the tension between innovation and safeguarding fundamental rights, requiring stronger institutional policies and compliance with global standards such as the General Data Protection Regulation (GDPR).

Equity and Access Issues

Although AI has potential to democratize learning, it can also widen existing inequalities in TVET. Learners in urban centers with robust digital infrastructure may benefit from adaptive platforms and simulations, while those in rural or underfunded colleges remain excluded due to poor connectivity, limited devices, and high costs (UNESCO, 2023). This digital divide undermines fairness in skills development, contradicting the principle of inclusive education. The dilemma lies in balancing AI adoption with equitable provision, ensuring that investments do not deepen socio-economic gaps among Nigerian learners.

Threats to Teachers' Professional Roles

AI-driven tutors, chatbots, and automated assessment systems raise concerns about the future of teachers' roles. While these tools are intended to complement instructors by reducing workload and supporting individualized guidance, there is a fear that excessive reliance on automation may undermine teachers' professional authority, reduce demand for certain teaching tasks, and deskill the profession (Samuel, 2023). In the TVET context, where mentorship and hands-on demonstration are essential, replacing rather than supporting teachers could compromise both instructional quality and the human dimension of vocational education.

Bias, Transparency, and Accountability in AI Systems

AI systems are only as fair as the data and algorithms that power them. If training datasets are incomplete, biased, or not context-specific, AI may generate skewed outcomes in student assessment, career guidance, or admission decisions (Nwanguma & Onyeukwu, 2024). Moreover, the "black box" nature of many AI tools creates opacity, making it difficult for teachers, learners, or administrators to understand how decisions are made. Without transparency and clear accountability structures, institutions risk embedding systemic discrimination into skills certification and labor market placement. Addressing this dilemma requires mechanisms for explainability, stakeholder oversight, and ethical auditing of AI tools deployed in TVET.

Implications for Skills Development in Nigeria

Opportunities for Workforce Competitiveness

AI integration in TVET presents opportunities to raise Nigeria's global workforce competitiveness by enhancing the quality and relevance of training. Adaptive learning platforms, simulation technologies, and predictive analytics can help align curricula with industry demands, preparing graduates with future-ready skills in automation, digital manufacturing, and service innovation (Omeh *et al.*, 2024). If harnessed effectively, these technologies could position Nigerian graduates

to compete not only in local labour markets but also in regional and international economies where digital literacy and technical adaptability are increasingly non-negotiable.

Challenges for Employability and Lifelong Learning

Despite its promise, AI also creates new challenges for employability and lifelong learning. Rapid technological change means that workers must continuously update their competencies to remain relevant. However, structural barriers such as inadequate funding for reskilling, weak institutional capacity, and poor industry–academia collaboration hinder this process (Ogunode & Abiodun, 2024). Without deliberate efforts to ensure equitable access to AI-enabled training, there is a risk that only elite institutions will produce employable graduates, leaving others with outdated or mismatched skills. Lifelong learning in TVET must therefore be reinforced through policies that promote flexible, inclusive, and technology-supported training pathways.

Alignment with National Development Goals

Nigeria’s development strategies, including the National Digital Economy Policy and Strategy (2020–2030) and the Sustainable Development Goals (SDGs), emphasize digitalization, innovation, and inclusive growth. AI-enabled TVET aligns with these goals by supporting human capital development, job creation, and poverty reduction (Federal Ministry of Education, 2019; NBTE, 2025). However, if ethical dilemmas such as inequitable access, privacy risks, or teacher displacement are not addressed, AI adoption may undermine these very objectives. Ensuring alignment therefore requires not only technological adoption but also policy safeguards and governance mechanisms that guarantee AI contributes to sustainable skills development, rather than reinforcing structural inequalities.

Policy and Regulatory Considerations

Nigerian Education and ICT Policies

Nigeria has taken significant steps to integrate digital technologies into education through policies such as the National Policy on ICT in Education (2019) and the National Digital Economy Policy and Strategy (2020–2030). These frameworks emphasize digital inclusion, innovation, and human capital development as drivers of socio-economic transformation (Federal Ministry of Education, 2019; NBTE, 2025). Within TVET, the National Board for Technical Education (NBTE) has encouraged digitalization of curricula, teacher upskilling, and the adoption of competency-based training models. However, gaps persist in implementation, including inadequate infrastructure, weak monitoring, and limited enforcement mechanisms. Without specific provisions for AI in TVET, these policies remain broad, leaving institutions to navigate ethical, legal, and pedagogical concerns on their own.

International Best Practices in AI Governance

Globally, organizations such as UNESCO, the OECD, and the European Union have developed principles to guide the ethical use of AI in education. These include transparency, accountability, fairness, inclusivity, and protection of human rights (UNESCO, 2023; OECD, 2021). Countries like Canada, Singapore, and Finland have implemented comprehensive AI strategies that incorporate education, emphasizing stakeholder engagement, teacher support, and data protection. Adopting and adapting these best practices can help Nigeria avoid pitfalls such as algorithmic bias, inequitable access, and misuse of personal data. Benchmarking against international standards

would not only strengthen local governance but also ensure Nigeria's TVET graduates are globally competitive.

The Need for Ethical Guidelines in TVET

While Nigeria's policy frameworks highlight the importance of digital technologies, they rarely address the specific ethical challenges of AI in vocational education. Issues such as data privacy, algorithmic bias, equity of access, and the professional autonomy of teachers demand tailored guidelines. Developing such ethical frameworks is essential to ensure that AI adoption supports inclusive learning and workforce preparation while protecting learners' rights and institutional integrity (Afolabi, 2024; Olukunle-Ajiye & Omokhabi, 2025). A clear set of ethical standards, co-created by policymakers, educators, industry stakeholders, and civil society would provide direction for institutions, build public trust, and ensure that AI strengthens rather than undermines the goals of TVET in Nigeria.

Strategies for Ethical Integration of AI in TVET

Teacher Training and Capacity Building

Teachers are the frontline implementers of AI-enhanced instruction, yet many lack the digital skills and ethical awareness needed to effectively use these technologies. Structured professional development programs should focus not only on technical competencies such as managing AI-enabled tools for assessment or simulation but also on understanding the ethical risks, including data misuse and bias (Balogun *et al.*, 2024). Partnerships between NBTE, higher education institutions, and industry players could create sustainable capacity-building initiatives that ensure instructors remain both technologically competent and ethically grounded.

Stakeholder Engagement and Awareness

The successful integration of AI in TVET requires broad-based participation from policymakers, educators, students, parents, and employers. Awareness campaigns and consultative forums can help clarify expectations, highlight potential risks, and build public trust in AI applications. International best practices suggest that co-creation of ethical guidelines with stakeholders enhances compliance and relevance (UNESCO, 2023; OECD, 2021). For Nigeria, inclusive dialogue would mitigate fears of job displacement, promote equity of access, and ensure that AI applications reflect cultural and contextual realities.

Curriculum Reforms for Digital and Ethical Literacy

Embedding AI in TVET calls for curriculum reforms that emphasize digital fluency alongside ethical reasoning. Learners must be trained not only to operate AI systems but also to critically examine their limitations and consequences. This includes modules on digital rights, responsible data use, algorithmic fairness, and workplace ethics (Olukunle-Ajiye & Omokhabi, 2025). Such reforms would produce graduates who are both technically proficient and ethically conscious, equipping them to navigate complex technological work environments responsibly.

Inclusive and Responsible AI Design

AI systems deployed in TVET must be designed with inclusion, fairness, and accountability in mind. This requires transparency in algorithms, safeguards for learner data, and deliberate efforts to avoid reinforcing social inequalities. Developers and education authorities should adopt standards that prioritize accessibility for disadvantaged groups, including learners in rural areas

and those with disabilities (Afolabi, 2024). By promoting responsible AI design, TVET institutions can ensure that technology enhances rather than undermines equitable skills development.

Conclusion

Artificial intelligence (AI) is rapidly transforming the global education landscape, and its influence on Technical and Vocational Education and Training (TVET) in Nigeria is increasingly evident. The review has shown that AI offers remarkable opportunities for enhancing teaching, learning, assessment, and institutional management, while also raising critical ethical dilemmas around data privacy, equity of access, teacher roles, and accountability. These dilemmas are particularly important in the Nigerian context, where infrastructure limitations, funding constraints, and uneven policy implementation widen the gap between digital aspirations and operational realities. This study contributes to knowledge by situating AI adoption in Nigerian TVET within broader debates about skills development and ethical practice. It highlights the need for context-sensitive frameworks that not only leverage the potential of AI for workforce competitiveness but also safeguard inclusiveness, fairness, and professional integrity. Addressing these issues is essential if Nigeria is to achieve sustainable skills development and align TVET reforms with its national and global development goals.

Recommendations

Based on the findings of the study, the following recommendations were made:

1. Federal Ministry of Education and the National Board for Technical Education should, by 2027, develop and enforce a national ethical framework for artificial intelligence in TVET that addresses data privacy, teacher roles, and equitable access, adapting global best practices to Nigeria's context.
2. TVET institutions should, within the next three years, implement structured artificial intelligence capacity-building programs for teachers in partnership with information technology firms and universities, focusing on both technical use of artificial intelligence tools and ethical awareness.
3. Government agencies such as the National Board for Technical Education, the National Information Technology Development Agency, and the Nigerian Communications Commission should, by 2027, expand digital infrastructure to rural and underserved TVET institutions, ensuring at least 60 percent nationwide coverage with reliable internet and secure artificial intelligence-compatible devices.
4. The National Board for Technical Education should, starting from the next academic cycle, revise TVET curricula to include digital and artificial intelligence ethics literacy modules, equipping graduates with both technical skills and ethical competencies for the workplace.

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REIMAGINING BIOLOGY INSTRUCTION IN COLLEGES OF EDUCATION: THE POTENTIAL OF VIRTUAL VIDEO-BASED PACKAGES

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Abstract

Virtual video-based instructional packages offer significant potential to transform biology education in Colleges of Education. Traditional teaching remains largely teacher-centered, constrained by limited resources and challenges in conveying abstract concepts, resulting in low student motivation and retention. Evidence from recent research highlights the pedagogical advantages of video-based learning, including enhanced engagement, improved comprehension and flexible access to content. Effective implementation requires curriculum alignment, lecturer preparation, robust infrastructure and integration into blended or flipped classroom models. Key considerations include bridging the digital divide, managing production costs, ensuring sustainability and providing ongoing professional development for lecturers. Systematic adoption, supported by training and policy frameworks, can maximize learning outcomes and equip pre-service teachers with the skills needed for modern, technology-enhanced classrooms. These insights underscore the importance of embracing virtual video-based packages as a strategic innovation in teacher education.

Keywords: *Biology Education, Blended Learning, Colleges of Education, Digital Divide, Instructional Package and Video-Based Learning*

Introduction

Biology remains a cornerstone discipline in Colleges of Education, yet its teaching is often constrained by outdated approaches. Reliance on lecture methods has created classrooms where learners become passive recipients rather than active participants (Ssemugenyi, 2023). This limited interactivity hampers deep understanding of biological processes that are best grasped through visualisation and exploration. Studies in biology education highlight the importance of engaging learners through approaches rooted in conceptual and theoretical frameworks (Luft *et al.*, 2022). Moreover, the National Academies of Sciences *et al.* (2021) stress the value of biological education for the 21st century, underscoring its role in preparing students for scientific inquiry and problem solving. However, persistent gaps in resources and teaching strategies continue to undermine these aims.

Modern educational research suggests that technology, if thoughtfully integrated, can bridge these gaps. Wang (2024) and Rafiq *et al.* (2024) note that digital tools significantly enhance student learning outcomes, particularly when combined with interactive designs. In this context, video-based learning (VBL) has gained prominence as a flexible and effective strategy. Reviews by Sablić *et al.* (2021) and Navarrete *et al.* (2025) show that video packages can improve engagement, motivation and retention when tailored to learners' needs.

Current Challenges in Biology Education

Biology instruction in Colleges of Education continues to be dominated by teacher-centred practices where lectures remain the primary mode of delivery. While effective in covering large portions of content, this method often sidelines learner participation and discourages critical engagement with scientific ideas (Ssemugenyi, 2023). The consequence is a classroom culture where students memorise rather than understand, limiting their capacity to apply knowledge in real contexts. The scarcity of instructional resources, including modern laboratories and interactive teaching aids, further compounds this problem, creating inequities in how biology is experienced across institutions (National Academies of Sciences *et al.*, 2021).

Beyond structural constraints, the nature of biology itself presents learning challenges. Abstract concepts such as cellular processes, genetic mechanisms, or ecological interactions are difficult to visualise, frequently resulting in cognitive overload when taught through text-heavy lectures (Luft *et al.*, 2022). This struggle contributes to low motivation, poor retention and declining achievement levels, as learners find it hard to connect theory with lived experiences (Adonu *et al.*, 2021). Access to modern instructional technologies that could bridge this gap remains limited, leaving many educators without the tools to enrich teaching. Without targeted innovations, these persistent challenges risk undermining the preparation of future biology educators and the broader goals of science education.

Pedagogical Potential of Virtual Video-Based Packages

The integration of virtual video-based packages into biology teaching is strongly underpinned by established learning theories. Mayer's Cognitive Theory of Multimedia Learning suggests that students learn more effectively when information is presented through both verbal and visual channels, reducing cognitive overload and strengthening retention. Similarly, Constructivist principles highlight the value of active engagement, where learners build their own understanding through interaction with materials. Virtual video packages, with their mix of narration, imagery and interactivity, align well with these frameworks by offering a scaffolded and immersive environment for learners (Dahlan *et al.*, 2023).

Beyond theory, evidence from recent research demonstrates their effectiveness in enhancing learning outcomes. Navarrete *et al.* (2025) note that video-based learning improves motivation, comprehension and long-term retention when designed with clear pedagogical goals. Poudyal (2023) reports that audio-visually enriched approaches in anatomy and physiology classes improved both student performance and satisfaction, while Lewis (2024) stresses that technology-driven pedagogy fosters learner autonomy and deeper engagement. Practical tools such as Canva enable educators to design customised video resources, supporting flipped and blended learning approaches (Kovtaniuk *et al.*, 2025). In this way, virtual video-based packages not only provide accessibility and flexibility but also empower students to learn at their own pace, strengthening achievement and fostering independent, lifelong learning habits (Howze-Owens, 2021).

Implementation Prospects virtual video-based packages in Colleges of Education

Curriculum Alignment Strategies

Aligning virtual video-based packages with existing biology curricula is essential for meaningful integration. Research emphasises that blended and innovative models must complement rather than compete with curricular frameworks to maintain coherence (Nguyen, 2024). Embedding videos into prescribed modules ensures that students meet learning objectives while benefiting

from interactive and visual support. Such alignment allows for reinforcement of core topics while extending opportunities for application and exploration beyond traditional lectures.

Moreover, carefully designed alignment can bridge gaps between theory and practice. By using videos to enhance learning outcomes, lecturers can create clear progression routes that foster continuity across lessons. Mulenga and Shilongo (2025) highlight how hybrid and blended learning strategies succeed when pedagogy, curriculum and assessment are aligned. In biology education, this could involve integrating video demonstrations of experiments or ecological case studies that bring abstract ideas to life while preserving curricular integrity.

Teacher Preparation and Professional Development

Teacher readiness is critical to the success of virtual video-based learning. Without adequate training, even the most innovative tools risk underuse. Zhang *et al.* (2025) show how institution-driven blended learning programmes can provide scalable professional development, ensuring lecturers are confident in both content creation and delivery. This preparation equips teachers with the digital literacy required to adapt existing materials into engaging video-based resources aligned with biology instruction.

Professional development also empowers teachers to adopt new pedagogical roles. Rather than being sole knowledge transmitters, lecturers become facilitators who guide students through interactive video-based tasks. Nkanyani (2023) stresses that tailored training enables teachers to shift smoothly into blended or flipped models, especially in resource-limited contexts. In this way, investment in professional development fosters not only competence but also enthusiasm for integrating digital strategies that enhance student learning experiences.

Infrastructure Requirements (Devices, Internet, Electricity)

Robust infrastructure forms the backbone of implementing video-based instruction. Access to functional devices, reliable internet and stable electricity ensures that students and lecturers can engage with video packages seamlessly. Studies underline how infrastructural gaps, especially in rural and underfunded institutions, pose serious barriers to blended learning adoption (Mulenga and Shilongo, 2025). Addressing these challenges requires institutional and governmental commitment to investing in digital infrastructure that matches pedagogical ambitions.

At the same time, infrastructure must be sustainable and adaptable. Low *et al.* (2021) argue that when technology integration is supported by scalable infrastructure, the benefits of flipped and blended models are maximised. For Colleges of Education, this means planning beyond short-term solutions and ensuring that devices, platforms and connectivity are maintained and upgraded over time. Reliable infrastructure transforms video-based instruction from an occasional tool into a standard, dependable aspect of biology teaching.

Integration into Blended or Flipped Classroom Models

Integrating video-based packages into blended or flipped classroom models offers a practical route to innovation. Aidoo *et al.* (2022) demonstrate how the flipped approach enabled continuity during COVID-19, allowing students to engage with content before class and use contact time for deeper discussion. In biology, pre-recorded lectures or experimental demonstrations could classroom

sessions for problem-solving, group work, or clarification of complex ideas, making learning more interactive and effective.

Furthermore, lecturers' perspectives reveal both opportunities and challenges. Ramulumo *et al.* (2024) note that while flipped models encourage autonomy and active participation, success depends on student commitment and teacher adaptability. Blended frameworks also provide flexibility, accommodating diverse learning needs (Nguyen, 2024). In Colleges of Education, combining video-based resources with traditional teaching fosters a dynamic balance: technology enriches content delivery while face-to-face sessions maintain the personal guidance crucial to effective science education.

Table: Summary of Reviewed Studies on Video-Based Learning (2021–2025)

Author(s) and Year	Location / Area of Study	Research Methodology / Sample	Results / Findings
Sablić <i>et al.</i>, 2021	Global (Review of VBL research from 2008–2019)	Systematic literature review	VBL has evolved significantly, improving engagement, motivation and retention across disciplines. Effective design features include interactivity, multimedia integration and learner control.
Howze-Owens, 2021	USA	Doctoral study / Faculty training participants	Audio and video feedback improved teaching presence, enhanced student engagement and supported multimodal teaching practices in online learning environments.
Pal and Patra, 2021	India	Quantitative / University students	Students' perceptions of VBL during COVID-19 were positive; perceived usefulness and task–technology fit significantly influenced adoption and satisfaction.
El-Ariss <i>et al.</i>, 2021	UAE	Experimental / Structural steel design course students	Integrating video content into blended e-learning improved conceptual understanding, learner satisfaction and course performance.

Author(s) and Year	Location / Area of Study	Research Methodology / Sample	Results / Findings
Mohd Adnan, 2021	Malaysia, Indonesia, Brunei	Comparative study / Higher education students	VBL supported Higher Education 4.0 objectives, promoting flexible, self-paced learning and bridging geographical barriers in Southeast Asia.
Kunle and Nwaozuzu, (2022)	Developing Africa (general context)	Conceptual study on integration of process-based learning (animated cartoon) into post-primary education	Highlighted opportunities for improving engagement and comprehension but noted infrastructural and resource challenges limiting large-scale adoption.
Myburgh, 2022	South Africa	Design-based research / Biology students	Virtual lab experiences using VBL enhanced practical understanding and experimental skills, offering viable alternatives to physical labs.
Kunle and Nwaozuzu, 2022	Nigeria	Qualitative / Post-primary education analysis	Process-based animated VBL improved learners' comprehension of complex topics but faced infrastructural and policy-related challenges in developing contexts.
Thompson et al., 2022	UK	Review / Orthopaedic surgical education	VBL will play a crucial role in future medical education, especially in simulation-based training and skill development.
Pasawano and Quainoo, 2023	Ghana	Survey / Continuing education learners	Blended platforms integrating video content maintained learning continuity during COVID-19, with increased flexibility and learner satisfaction.
Dahlan et al., 2023	Malaysia	Mixed methods / Undergraduate students	Interactive video approaches improved engagement, comprehension and knowledge retention, highlighting the need for pedagogical design alignment.

Author(s) and Year	Location / Area of Study	Research Methodology / Sample	Results / Findings
Olelewe <i>et al.</i> (2023)	Nigeria (Computer Networking Course context)	Experimental study with students enrolled in networking course	Video-clip instructional strategy significantly improved students' performance, making learning more interactive and effective compared to traditional teaching.
Khomyshak, 2024	Ukraine	Analytical review	Identified key opportunities (personalised learning, accessibility) and challenges (infrastructure, digital divide) in adopting VBL in the digital era.
Schick <i>et al.</i>, 2024	Germany	Experimental / Medical students	Video modelling and reflection significantly enhanced communication competence, demonstrating VBL's effectiveness in skills-based learning.
Navarrete <i>et al.</i>, 2025	Global	Systematic review / 64 studies	Comprehensive synthesis showed that well-designed VBL significantly improves learning outcomes. Effective videos include high interactivity, adaptive features and targeted feedback mechanisms.

Challenges and Considerations

Digital divide and infrastructural limitations

The persistence of the digital divide remains one of the greatest challenges in implementing technology-driven learning. Memon and Memon (2025) emphasise that inequalities in access to devices, reliable internet and electricity create barriers among students. Studies such as Sydorenko *et al.* (2024) highlight how infrastructural gaps prevent inclusive participation. Addressing these divides requires sustained investment and innovative strategies, otherwise blended learning risks deepening rather than reducing educational inequality.

Cost of production and sustainability

Developing high-quality digital resources such as videos, simulations, or interactive courseware is costly and sustaining these innovations is even more demanding. Shirazi and Hajli (2021) note that IT-enabled innovations often falter without proper funding models, while Mugomba and Dube (2025) argue that universities in developing regions struggle with limited budgets for technological

upkeep. Without clear sustainability frameworks, initial enthusiasm for digital learning materials risks fading, undermining their long-term educational impact.

Need for continuous updating of materials

Digital learning materials cannot remain static; they require constant refreshing to reflect new knowledge, evolving pedagogies and technological upgrades. Sydorenko *et al.* (2024) caution that outdated materials quickly reduce relevance and learner motivation. Similarly, Bampasidou *et al.* (2024) demonstrate how fields like digital agriculture demand frequent content updates to keep pace with innovation. Thus, institutions must commit to periodic review and revision cycles, ensuring content remains current, engaging and pedagogically sound.

Training needs for lecturers

For blended and digital learning initiatives to succeed, lecturers require ongoing professional development. Mugomba and Dube (2025) highlight how limited ICT competence among academics in Zimbabwean universities hampers effective delivery. Beyond basic training, Memon and Memon (2025) stress the importance of equipping educators with pedagogical strategies for digital environments. Investing in continuous lecturer training not only boosts confidence and teaching quality but also ensures that technology serves as a meaningful tool rather than a daunting burden.

Conclusion

Virtual video-based instructional packages hold strong potential to transform biology education in Colleges of Education by making complex concepts more accessible, engaging and memorable for learners. However, their effectiveness depends on systematic integration into the curriculum, alongside well-planned teacher training that empowers lecturers to use them confidently. Supportive institutional and national policies are equally essential to ensure sustainability and equity. This perspective serves as a call to action for educators, policymakers and stakeholders to embrace and invest in these innovations for long-term educational improvement.

Recommendations

Practice: Encourage adoption of virtual video-based packages in biology classrooms.

Policy: Support from education ministries and institutions to fund and sustain technology integration.

Research: Call for empirical studies on effectiveness, scalability and long-term impacts.

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ASSESSMENT OF ENVIRONMENTAL AND HUMAN HEALTH IMPACT OF INFORMAL E-WASTE RECYCLING IN SABON GARI LOCAL GOVERNMENT, KADUNA, NIGERIA

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Abstract

E-waste describes electrical and electronic equipment or parts of it that have been discarded by the owner without any intention of reuse. The annual global volumes of e-waste are rapidly increasing. In Nigeria, the increasing quantities of e-waste have created avenue where the recovery of inherently valuable fractions from e-waste is performed by a dominating informal recycling sector using crude and primitive recycling procedures which pollute soil, water and the atmosphere with consequent threats to human health and the environment. This study examines the level and extent of heavy metal pollution and contamination at the Muchia e-waste processing site in Sabon gari, the ecological risks the metals pose, the carcinogenic and noncarcinogenic health risk of these heavy metals to children under six years. Methods used were experimental elemental analysis of 6 heavy metals (Cadmium Cd, Copper Cu, Chromium Cr, Nickel Ni, Lead Pb, and Zinc Zn), The analysis of the selected heavy metals revealed that the concentrations at the Muchia e-waste processing site exceeded the regulatory limits of the NESREA, Dutch and Canadian Soil Quality and Guidance Values and that contamination extended beyond the main burning and dismantling sites of the informal recyclers to the residential areas. The health risk assessment using the hazard index for both carcinogenic and non-carcinogenic elements indicates that Cr and Pb with a hazard index 1.050 and 1.612 for non-carcinogenic and above the 1 threshold of unacceptable limit pose significant health risks (neurological and developmental disorders) to children under six (6) years. It can be concluded that an appropriate mix of legislation, infrastructure, and local and international collaboration, together with the ability to enforce and ensure the mainstreaming and integration of the informal recyclers could help minimize the environmental and health risks from e-waste processing in Nigeria.

Keywords: e-waste, soil contamination, heavy metals, informal recycling, environmental risk

Introduction

The terms “E-waste”, “electronic waste” and “Waste from Electrical and Electronic Equipment (WEEE)” are used to refer to discarded and nonfunctional electronics. E-waste is different from functional secondhand electrical and electronic equipment, also called “Used Electrical and Electronic Equipment (UEEE)”. E-waste can come from a large variety of products that have plugs or batteries, such as computers, phones, washing machines, air conditioners, lamps, cameras, and more. According to estimates, over 50 million tons of e-waste are generated globally each year, and this amount is projected to reach 120 million tons per year by 2050 (World Economic Forum, 2019). However, in 2019, less than 20% of e-waste is properly recycled, and most of the e-waste is informally recycled in an uncontrolled manner (Forti *et al.*, 2020). Although informal recycling

widely exists in many regions of the world, most activities are in low- and middle-income countries.

High volumes of e-waste have been shipped to Asia and Africa countries, including Nigeria, where e-waste regulations are less restrictive (World Economic Forum, 2019). The proliferation of internet technology, the emergence of "smart cities" in both developed and developing countries, the constant evolution of personal electronic products, and the growing use of solar panels to tackle the climate crisis have all led to a surge in e-waste generation (Jon Hurdle, 2023). The soaring amount of e-waste has raised significant concerns, posing threats to public health and the environment, particularly in developing countries. Informal recycling is often unregulated and fails to meet safety or national environmental standards, posing a threat to worker's health and releasing toxic chemicals into the environment.

Primitive techniques such as dismantling, open burning, metal stripping, acid washing, dumping, etc., are commonly used to extract valuable components from e-waste (Chi *et al.*, 2011). Studies suggest that workers in the informal sectors usually lack protective equipment, such as gloves or masks, to shield them from exposure (Chi *et al.*, 2011). For example, workers use their bare hands to dismantle large equipment, which often causes cuts and muscle discomfort (Acquah *et al.*, 2021). Another common technique involves heating or burning cables and circuit boards to recover valuable metals like copper and melt unwanted plastic; this process can release toxic chemicals into the atmosphere and irritate workers' eyes and respiratory tracts during their works (Wang *et al.*, 2020). After heating, the remaining part of circuit boards is washed by highly corrosive acids to extract gold, and the acid wastewater, along with other pollutants such as heavy metals, may be dumped into nearby rivers (Wang *et al.*, 2020).

E-waste informal recycling can have a negative impact on human health. However, the associated adverse health effects depend on a variety of factors, and different individuals may have different health outcomes, even living in the same area. The time window of exposure (whether during pregnancy, early childhood, or adult life), e-waste recycling working history, living distance from polluted sites, and co-exposure from other pollutants, can all lead to different health consequences. For example, different types of e-waste recycling jobs can pose different levels of risks. A study found that smelting workers tend to be exposed to higher amounts of hazards than dismantlers and repairers, likely due to poor ventilation in working environments, and more toxicants can be released into the atmosphere by heating (Tahir *et al.*, 2021). Behavioral factors also matter, children who wash their hands more frequently were exposed to lower levels of heavy metals (Xu *et al.*, 2020), and different dietary habits can result in different PCBs exposure from food ingestion (Hashmi *et al.*, 2022).

A larger number of the populace that reside around such primitive recycling factories are at higher risk due to their continual exposure to harmful materials emanating from the recycling activities and processes that are mostly done without any safety measures. This study therefore focused on the assessment of the environmental impacts and possible health risks of potentially toxic metals emanating from e-waste related anthropogenic activities in Muchia, Sabon Gari local Government of Zaria, Kaduna State Nigeria.

Materials and methods

Study Area

The study area lies within Sabon Gari Local Government Area, Nigeria with a land area of approximately 600 square kilometers. It is bounded in the North by Ikara Local Government, to Makarfi Local Government in the North-West, Giwa Local Government to the West and Zaria Local Government to the South. Sabon-Gari LGA comprises several sub-settlements, namely, Samaru, Hayin-Dogo, Bomo, Dogarawa, Zango, Palladan, Hanwa, Chikaji, Muchia.

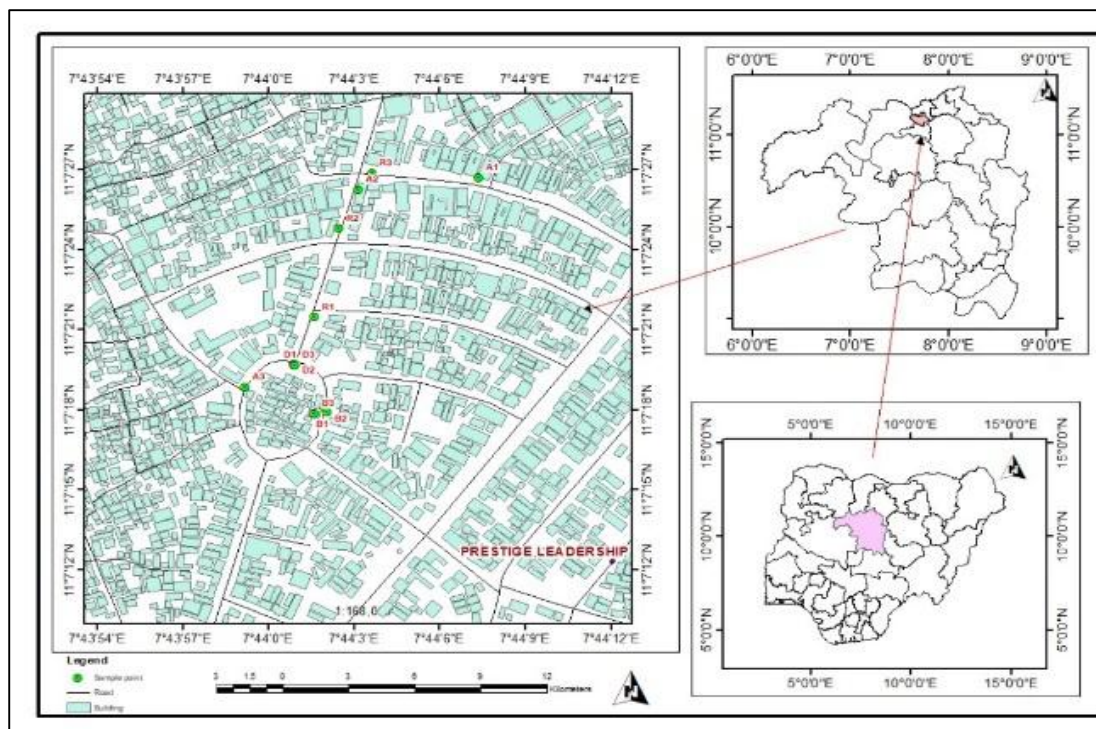


Figure 1.0: Kaduna State showing Study Area

Soil Samples Collection

Soil sampling was done over the entire Muchia e-waste recycling site and its surroundings, i.e. within the areas for dismantling, burning, and residential. A total of 20 samples was collected from the area using a grid and purposive sampling procedure.

Sampling Preparation

The samples were air dried at room temperature, sieved using a 100 μ m mesh, and pulverized into a 2.5 cm diameter thick pellet. Using acid tone, the equipment was cleaned after each procedure to avoid cross contamination.

Digestion of Samples

Each powdered sample was digested according to standard method of digestion. 1g of the sample was weighed into 50 ml beaker, 2.5mls of hydrochloric acid and 7.5 ml of nitric acid aqua regia solution (1:3) was added. The beaker containing the mixture was put on a hotplate set at a

temperature range of 100-170 °C until it was about to dry off or precipitate was observed. Removed and allow to cool, then added some drops of Distilled water. The solution was mixed-up and transferred to funnel set with filter paper. The filtrate was measured and made up to 50 ml. Finally, digests were transferred to the sample bottles for AAS analysis.

Determination of Heavy Metals

Heavy metals in the soil samples were determined according to method reported by Vinogradova *et al.* (2023) using Atomic Absorption Spectrometry (AAS) in which Pb, Cu, Cr, Ni, Zn, and Cd were estimated in the soil samples.

Data Preparation and Exploratory analysis

The heavy metal concentrations values together with the coordinates were prepared and arranged in Microsoft Excel and then loaded into R statistical software for the exploratory analysis. The descriptive variables assessed included the mean, median, minimum, maximum, standard deviation and skewness of the heavy metal concentrations. The heavy metal concentration variables were also analyzed for normality.

Contamination and Ecological Risk Assessment

The assessment of contamination was conducted based on the contamination factor and the degree of contamination. The estimation of the contamination factor in this study was based on

$$C_f^i = \frac{C_{0-1}^i}{C_n^i} \quad (1)$$

and that of the degree of contamination, which is the sum of all contamination factors at a location;

In addition, the ecological risk assessment based on ecological risk factors was conducted and potential ecological risk index determined.

$$C_{deg} = \sum C_f^i \quad (2)$$

$$E_R^i = T_r^i \times C_r^i \quad (3)$$

Health Risk Assessments

The human health risk was assessed as a measure of exposure of a person, and in this case children, to heavy metals. The USEPA (1996) model developed for human health risk was adopted in this study. In this study, the assessment was done based on the three pathways of exposure inhalation, dermal contact and by ingestion

$$Dinh = c(mg/kg) \times \frac{inhR \times EF \times ED}{PEF \times BW \times AT} \quad (4)$$

$$D_{\text{derm}} = c(\text{mg/kg}) \times \frac{SA \times ABS \times EF \times ED}{BW \times AT} \times 10^{-6} \quad (5)$$

$$D_{\text{ing}} = C \left(\frac{\text{mg}}{\text{kg}} \right) \times \frac{\text{ingR} \times EF \times ED}{BW \times AT} \times 10^{-6} \quad (6)$$

The human health risk due to exposure to heavy metals was estimated, while this was dependent on the hazard quotient determined. The health risk assessment in this study was estimated per the clusters within the Muchia e-waste site.

Results And Discussion

Descriptive Statistics

The skewness values for Cu, Cr and Cd were relatively low (Table 1.0). However, values for Pb, Zn, and Ni were high, which indicates non-normality of the dataset for these heavy metals. The significant differences between the mean and the median of all heavy metals also prove that the datasets were not normally distributed. Furthermore, the coefficients of variation (CV) of Pb and Ni were 1.82 and 6.05 respectively, and higher than those of Cu, Cr, Zn and Cd, suggesting that the former had greater variation among the soils in the study area

Table 1.0: Summary Statistics for Heavy Metal Concentration (ppm) in Soil

Based on the NESREA, Dutch and the Canadian environmental quality standard for soils, the

Heavy metals	Mean	Median	Min	Max	Stdv	CV	Skewness	NESREA	Dutch SQGV		Canadian SQGV
									Optimal	Action	
Pb	95321	290.95	14.20	1734.84	1734.84	1.82	3.29	40.00	85	530	140
Cu	46.64	35.25	8.80	153.70	29.17	0.63	1.12	100.00	20	240	-
Cr	296.60	197.30	21.10	1332.00	273.26	0.92	1.57	-	100	380	64
Ni	61.68	13.95	0.60	4003.00	373.36	6.05	10.59	0.05	35	210	40
Zn	1371.14	576.55	41.90	12907.50	1923.75	1.40	3.07	-	40	720	200
Cd	6.56	3.85	0.40	26.50	6.84	1.04	1.35	3.00	1	12	10

mean values of the heavy metal concentrations of Pb and Zn were above the optimal and action values of the NESREA, Dutch and Canadian soil quality and guidance values (SQGV), while those of Cd, Cu, and Ni were below the action-required values. It is also worth indicating that all heavy

metals apart from Cu showed maximum concentrations significantly above the action-required values.

Contamination Factor

Table 1.2 shows summary statistics on the calculation of contamination factor with the detailed location by location contamination factors. According to the Hakanson (1980) classification (Table 1.2) mean contamination factors of Cu, Cr and Ni were 1.86, 2.94 and 0.37, respectively, and thus indicate moderate contamination. The mean contamination factors of Cd, Pb and Zn were approximately 5, 11 and 3 times, respectively, above the lower limit of the high contamination factor. Zn, and Pb showed the highest coefficient of variation in the order 1.15, and 1.62, respectively, while Cd, Ni, Cr, and Cu showed the lowest in the order 1.04, 1.01, 0.90 and 0.61 respectively.

Table 1.2: Summary Statistics of Contamination Factors of Heavy Metals in Soil

Heavy metals	Mean	Median	Stdv	Min	Max	Cv	Skewness
Pb	70.25	23.27	113.64	1.14	472.24	1.62	2.63
Cu	1.86	11.41	1.14	0.35	5.16	0.61	0.99
Cr	2.94	1.98	2.64	0.21	10.99	0.90	1.40
Ni	0.37	0.91	0.37	0.01	1.41	1.01	1.18
Zn	17.85	8.24	20.51	0.60	77.11	1.15	1.60
Cd	32.80	19.25	34.20	2.00	132.50	1.04	1.35

Ecological risk factors

The ecological risk factor for each heavy metal under investigation as well as the overall potential ecological risk were calculated using Equations 2 and 3. The purpose of the assessment is to provide an empirical basis for understanding the ecological risks associated with these heavy metal concentrations in the soils of the Muchia e-waste processing site. The assessment was conducted based on four heavy metals where the toxicity response factor is provided by Hakanson (1980). Table 1.3 lists the summary statistics of the ecological risk factors with detailed potential ecological risk factor for each heavy metal.

Table 1.3: Summary Statistics of Ecological Risk Factors of Heavy Metals

Heavy metals	Mean	Median	Stdv	Min	Max	Cv	Skewness
Pb	351.24	116.38	568.33	5.68	2361.20	1.62	2.63
Cr	5.58	3.95	5.27	0.42	21.98	0.90	1.40
Zn	17.85	8.24	20.51	0.60	77.11	1.15	1.60
Cd	984.02	577.50	1026.51	60.00	3975.00	1.04	1.35

The mean and maximum Cr values show a “low ecological risk”, as the factors are all below 40. This also applies to the mean risk factor for Zn, however, the maximum value indicates moderate ecological risk. The mean and maximum ecological risks for Cd, and Pb are significantly high with a value above 320. The order of the level of heavy metal toxicity is Cd>Pb>Zn>Cr, indicating that these metals will in this order contribute significantly to the potential ecological risk in the study area.

Health Risk Assessment of Heavy Metals

The highest mean concentration of the heavy metals alternated between the burning and dismantling sites (Table 1.4), which is not surprising as the main activities of e-waste processing take place there. Cd, and Pb showed the highest mean concentrations in the burning sites, while Cu, Cr, Ni and Zn showed the highest values in the dismantling sites.

Table 1.4: Mean Concentration of Heavy Metal per site Cluster

Site	Pb	Cu	Cr	Ni	Zn	Cd
Burning	2666.38	43.81	171.53	21.84	1887.23	10.10
Dismantling	846.84	66.12	419.20	44.64	1939.22	7.81
Residential	896.06	51.53	153.87	44.64	1170.41	2.63

Exposure Pathways of Heavy Metals

Tables 1.5, 1.6 and 1.7 provide the hazard quotients per exposure pathway of Cd, Cu, Cr, Ni, Pb and Zn. The exposure pathways are in the order inhalation Cr> Pb) were the two heavy metals with the highest hazard quotients, and a similar trend was also seen for the dermal pathway. It is also however worth noting that Ni and Zn had the lowest hazard quotient in all three exposure pathways.

Table 1.5: Hazard quotient for dermal exposure pathway for heavy metal.

Hazard quotient (dermal exposure pathway)						
Area	Pb	Cu	Cr	Ni	Zn	Cd
Burning	9.35E-02	5.04E-05	5.26E-02	7.45E-05	5.79E-04	1.86E-02
Dismantling	2.97E-02	7.61E-05	1.29E-01	1.52E-04	5.95E-04	1.44E-02
Residential	3.14E-02	5.93E-05	4.72E-02	7.27E-05	3.59E-04	4.83E-03

Table 1.6: Hazard quotient for inhalation exposure pathway for heavy metal.

Hazard quotient (inhalation exposure pathway)						
Area	Pb	Cu	Cr	Ni	Zn	Cd
Burning	9.33E-04	1.41E-03	1.10E-03	7.43E-07	5.78E-06	1.86E-04
Dismantling	2.96E-04	2.13E-03	2.69E-03	1.52E-06	5.94E-06	1.43E-04
Residential	3.14E-04	1.66E-03	9.88E-04	9.25E-07	3.58E-08	4.82E-05

Table 1.7: Hazard quotient for ingestion exposure pathway for heavy metals

Area	Pb	Cu	Cr	Ni	Zn	Cd
Burning	5.01e+00	1.44E-02	3.76E-01	7.18E-03	4.14E-02	6.64E-02
Dismantling	1.59E+00	2.17E-02	9.19E-01	9.47E-02	4.25E-02	5.13E-02
Residential	1.68E-00	1.69E-02	3.37E-01	8.94E-03	2.57E-02	1.73E-02

Tables 1.5 shows the Hazard quotient for dermal exposure pathway for heavy metals in soil in the study area. The exposure pathways are in the order dermal shows that Cr, Pb were the two heavy metals with the highest hazard quotients.

Tables 1.6 shows the Hazard quotient for inhalation exposure pathway for heavy metals in soil in the study area. The heavy metal Cr showed the highest hazard quotient through inhalation, followed by Pb

Table 1.7 shows the Hazard quotient for ingestion exposure pathway for heavy metals. The exposure pathways in the order of ingestion. (Cr and Pb) were the two heavy metals with the highest hazard quotients, and a similar trend was also seen for the dermal pathway.

Non-carcinogenic Health Risk of Heavy Metals The non-carcinogenic health hazard indices of Cd, Cu, Ni and Zn for children under 6 years in all study areas within the Muchia e-waste processing site were below the 1 reference limit of environmental and regulatory agencies below which hazards are considered acceptable for children. The value however of Cr in the

dismantling site were above the regulatory limit of 1 and considered unacceptable by environmental managers.

The indices for Pb in the areas of burning, dismantling and residential were above the reference limit of 1, and as such considered as unacceptable for children within these areas. In the case of the burning area, the non-carcinogenic hazard index for Pb was five times higher than the reference limit of 1. The high health hazard indices of Cr and Pb in the burning, dismantling and residential areas could be an indication that the activities there could be a contributing factor to the potential hazard posed by heavy metals.

Table 1.8: Non-carcinogenic hazard index for heavy metal in the study area

Area	Pb	Cu	Cr	Ni	Zn	Cd
Burning	5.104	0.016	0.085	0.007	0.042	0.085
Dismantling	1.612	0.024	1.050	0.150	0.043	0.066
Residential	1.715	0.015	0.385	0.009	0.026	0.022

Carcinogenic Health Risk of Heavy Metals

The carcinogenic risk was calculated based only on the risk through inhalation for four carcinogenic heavy metals (Cd, Cu, Cr and Ni) using the model as expressed in

$$LADD = \frac{C \times EF}{AT \times PEF} \times \left[\left(\frac{InhR_{child} \times ED_{child}}{BW_{child}} \right) + \left(\frac{InhR_{adult} \times ED_{adult}}{BW_{adult}} \right) \right] \quad (7)$$

The carcinogenic risk of these heavy metals due to activities within the Muchia e-waste processing site is low, as it is below the threshold range of values 10^{-4} and 10^{-6} . The index of these metals is in the order Cr>Cu> Cd>Ni with risk indices of Cd and Ni alternating depending on the site.

The health impact assessment of e-waste recycling activities within the Muchia e-waste processing site showed an overall health risk regarding both carcinogenic and non-carcinogenic effects of the heavy metals identified. With respect to the non-carcinogenic effect on children, the ingestion of particles from the Muchia e-waste processing site appears to be the exposure route with the highest impact followed by dermal contact and inhalation. A similar pattern was also observed by Ferreira-Baptista and De Miguel (2005); Lim *et al.* (2008); Khan *et al.* (2008) and Zheng *et al.* (2010) in their studies of exposure to heavy metals. The hazard quotients of non-carcinogenic risk due to inhalation of fine particles from the Muchia e-waste processing site is 1 to 4 orders of magnitude lower than that of ingestion and dermal contact. This makes the exposure to heavy metals through inhalation less risky to health, as according to Zheng *et al.* (2010) inhalation of re-suspended particles through the mouth and nose is almost negligible compared with ingestion and dermal contact. Furthermore, the above regulatory limits of the non-carcinogenic hazard index of Cr at all

sites and that of Pb in the burning, dismantling, residential areas, if contacted by children in high doses, can trigger neurological and developmental disorders (Ferreira-Baptista and De Miguel 2005; Zheng *et al.* 2010). Despite the low health hazard indices of Cd, Cu, Ni and Zn in the Muchia e-waste processing sites, these heavy metals can be cumulative and can affect the kidney (Burbure *et al.* 2003) and other vital human organs, and as such their exposure to children must be avoided.

Table 1.9: Carcinogenic Hazard Risk for Heavy Metals

Area	Cu	Cr	Ni	Cd
Burning	2.2E-08	3.69E-07	9.41E-10	3.26E-09
Dismantling	3.32E-08	9.03E-07	1.92E-09	2.52E-09
Residential	2.59E-08	3.31E-07	1.17E-09	8.48E-10

CONCLUSIONS

The environmental impacts of e-waste recycling were evaluated by assessing the concentration and extent of heavy metal contamination in the soils of the Muchia e-waste processing site, and the potential ecological risks the contamination poses to the environment. The following conclusions were drawn:

The results of the analysis reveal that the heavy metal concentrations were ubiquitous within the Muchia e-waste processing site, and that the concentrations in the soils exceeded the minimum and action required limits of the NESREA, Dutch and Canadian Soil Quality and Guidance Values by 10 to 1000 times. Contamination factor, degree of contamination and potential ecological risk indices employed to determine the level and extent of heavy metal pollution in soils at the Muchia e-waste processing site showed that the area is contaminated with six heavy metals, with Cd, Pb and Zn being the major contributors to the contamination in the soil and environment. The contamination and levels of the heavy metals measured in the soils at the Muchia e-waste processing site pose potential ecological risks to the environment of the Muchia e-waste processing site.

The health impacts from the e-waste recycling activities within the Muchia e-waste processing site were assessed by evaluating both the carcinogenic and non-carcinogenic health risks posed by exposure to heavy metal (Cd, Cu, Cr, Ni, Pb and Zn) to local inhabitants, specifically children under 6 years who are more susceptible to heavy metal exposure. The following conclusion can be drawn: In the Muchia e-waste processing site, the exposure pathway that results in the highest level of health risks to children exposed to the investigated heavy metals is ingestion of particles, with Cr and Pb being of most concern in all three exposure pathways.

The hazard indices of Cd, Cu, Ni and Zn were less than 1, thus indicating a relative absence of non-carcinogenic health risks related to the exposure pathways ingestion, dermal contact and inhalation. The hazard indices of Cr and Pb were above the threshold value of 1 for

noncarcinogenic hazard risks indicating possible triggers of neurological and developmental disorders in children.

The hazard indices for the four carcinogenic heavy metals Cd, Cu, Cr and Ni were below the threshold range of 10^{-4} to 10^{-6} indicating a relative absence of carcinogenic health risks. The index, however, of Cr in all areas is of concern as it is closest to the threshold range. The results of the health risk assessment of the exposure of heavy metals are affected by some degree of uncertainty related primarily to estimates toxicity and exposure parameters. The degree of uncertainty in the health risk assessment does not prohibit the use of the assessment to confirm or reject the existence of unacceptable levels.

Recommendations

Based on the revealed widespread contamination of the Muchia e-waste processing site with heavy metals, the potential ecological and health risks to the environment, humans, and aquatic and terrestrial species, it is recommended that:

Further studies need to be conducted on the activities of informal e-waste recyclers, and environmentally sustainable ways proposed to efficiently recover valuable metals from e-waste in Sabon Gari.

Given the level and spatial extent of the contamination, the ecological and health risks, urgent precautionary and remediation measures must be taken to prevent the further spread of the heavy metal contamination within the Muchia e-waste processing site.

The results of the health risk assessment for the exposure of heavy metals to children within the Muchia e-waste processing site were affected by some degree of uncertainty, which is mainly associated with toxicity estimate values, and only few exposure parameters in Nigeria. This underlines the need for further research into exposure and transport factors at the Muchia e-waste processing site that would help to reduce the currently considerable uncertainty associated with the risk assessment.

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TEACHERS' PERCEPTIONS ON USES OF ARTIFICIAL INTELLIGENCE ADAPTIVE LEARNING TOOLS TO ENHANCE ACADEMIC PERFORMANCE OF SECONDARY SCHOOLS STUDENTS IN MINNA METROPOLIS, NIGER STATE

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Abstract

This study investigates teachers' perceptions on the use of Artificial Intelligence (AI) adaptive learning tools and the academic performance of senior secondary students in Minna Metropolis, Niger State, Nigeria. The study adopted descriptive research survey type, and the population for this study is six hundred and eighty (680) Science Teachers in Minna Metropolis which comprised of the two LGAs Bosso and Chanchaga respectively. The instrument for data collection was a questionnaire titled Teachers' Perceptions Use of AI Adaptive Learning Tools Questionnaire (TPUALTQ) which was administered to two hundred and forty (240) Science Teachers randomly selected from the two local governments. The instrument was validated and tested for reliability. Cronbach Alpha was used to establish the reliability of the instrument which yielded reliability index of 0.80, descriptive statistics was used to answer the research question and Mann-Whitney u-test was used to test the hypothesis with the aid of Statistical Product and Service Solution (SPSS) version 25 at 0.05 level of significant. Finding revealed that there was positive perception of science teachers on impact and ease of use of AI adopted learning tools on academic performance of students with the grand mean of 3.50 on a four-point rating scale. There was significant difference in science teachers' perceived ease of use of AI adopted learning tools for science teaching based on gender. It is recommended that government and stakeholders in education should provide secondary schools with adequate and accessible AI tools and other digital devices for teaching/ learning science subjects, and teachers should engage in training and capacity building on the utilization of AI adopted learning tools in tutoring.

Keywords: Teachers, AI Adaptive Learning Tools, Academic Performance

Introduction

Teachers play a crucial role in shaping students' understanding and interest in scientific concepts, their expertise, instructional strategies, and ability to engage students directly influence how well learners grasp concepts and learning content. As agents of positive change, they are indispensable in the academic and professional development of students. In secondary schools, teachers are expected to simplify complex topics, foster critical thinking and create an interactive learning environment that encourages curiosity and problem-solving, the more inclusive they are in pedagogy the better chance students record high and effective academic performance. A teacher's characteristics such as mastery of content, professional knowledge, communication skills, and classroom management impact on students' motivation and attitude toward learning Drymiotou *et al.*, (2021). In an increasingly technological world, science education serves as the foundation for innovation, critical thinking and problem-solving skills.

Academic performance holds great significance as it serves as a gauge to measure students potential and learning achievements based on their historical behaviour, data and the ability to meet the educational goals of an institution Martin-Sanz *et al.*, (2019). Those students that excel beyond the average expectations set by high schools, and the society are not only regarded as intelligent but are seen to likely play a meaningful role in the future growth and development of their community and the nation at large. Academic performance in Nigeria is key metric used to evaluate students' effectiveness. It also encompasses a range of outcomes, including standardized test scores, classroom assessments and overall grades. Federal Republic of Nigeria FRN, (2014) underscore the importance of academic performance by emphasizing education as a tool for national development, individual self-fulfilment and global competitiveness. Thus, Academic performance is essential for student's progression to higher education and competitive job markets, directly influencing their future career prospects and socio-economic status.

Perception influence attitudes by shaping how information about something is viewed, thus perception is the interpretation of sensory input, influenced by past experiences and bias, it includes sensation and interpretation of how an object is viewed Abidoye, (2018). Teachers' perceptions of Artificial Intelligence technology are crucial, as they are the primary implementers and mediators between the tool and the learners. Their acceptance, scepticism, or resistance directly influences the tool's effectiveness, and consequently the overall student academic performance. Though teachers appreciate the automation of grading, assignment distribution, and progress tracking. Their views are shaped by the tool's ability to save time, provide actionable data, and personalize learning, but are tempered by concerns about dehumanization, equity, and their own professional autonomy.

Artificial Intelligence (AI) refers to the development of computer systems capable of performing tasks that typically require human intelligence, such as learning, reasoning, and problem-solving. AI in education has transformed conventional learning methods by introducing automation, personalized learning, and intelligent tutoring systems. AI-driven technologies have improved the efficiency of educational delivery thereby making teaching and learning more interactive and adaptive to students' needs (Adebayo, 2022). AI is increasingly transforming the education strategies through adaptive learning systems that tailor instruction to students' individual needs. These adaptive tools analyze learners' strengths and weaknesses, provide personalized feedback, and adjust content delivery to optimize learning. Johnson *et al.*, (2020) defined adaptive learning as pedagogical approach that modifies the path and pace of learning in real-time based on individual learner's interactions. Adaptive learning systems use algorithms to customize learning materials based on students' responses, these tools improve engagement, foster independent learning, and support differentiated instruction Holmes *et al.*, (2021). AI adaptive learning tools represent a paradigm shift in science education as it offers a way to master fundamental concepts thoroughly and engage with the material at a deeper, more personal level. AI adaptive learning tools hold significant potential to boost academic performance.

In the context of education, AI encompasses a range of technologies, including machine learning algorithms, natural language processing, and intelligent tutoring systems, designed to support teaching and learning processes. AI learning platforms, specifically, are digital environments that utilise these technologies to deliver personalised learning experiences, provide real-time feedback, and facilitate interactive tasks aimed at enhancing cognitive skills Chen *et al.*, (2020). These

platforms often incorporate features such as adaptive learning pathways, gamified problem-solving exercises, and data-driven insights to tailor educational content to individual learner needs. The relevance of AI learning platforms lies in their ability to move beyond traditional rote learning, fostering skills like critical thinking and problem-solving, which are essential for addressing complex, real-world challenges. Essentially, greatest academic gains are observed not in fully automated classrooms, but in blended learning environments where AI and teachers work in tandem. Teachers' familiarity with such platforms is vital, as they will blend and integrate the digital tools with conventional strategy in classrooms thereby shaping the next generation of learners. In general, AI learning platforms support problem-solving by offering interactive simulations, scenario-based tasks, and data-driven insights that guide learners through the problem-solving process.

Purpose of the Study

The purpose of this study is to find out Teachers' Perceptions on the use of AI Adaptive Learning Tools in enhancing Academic Performance of Senior Secondary Students in Minna Metropolis. Specifically, the objectives of the study is to:

- i. determine teachers' perceptions on the use of AI adaptive learning tools in enhancing academic performance of senior secondary school students in Minna metropolis
- ii. find out gender differences in teachers' perceptions on the use of AI adaptive learning tools in enhancing academic performance of senior secondary school students.

Research Questions

The following research questions are formulated on the basis of the stated specific objectives:

- i. What is the level of teachers' perceptions on use of AI adaptive learning tools in enhancing academic performance of secondary schools' students in Minna metropolis?
- ii. What are the differences in male and female teachers' perceptions on the use of AI adaptive learning tools in enhancing academic performance of senior secondary school students?

Research Hypothesis

HO₁: there is no significant differences in male and female teachers' perceptions on the use of AI adaptive learning tools in enhancing academic performance of senior secondary school students.

Methodology

The study adopted a descriptive survey research design. This design is appropriate for obtaining quantitative data from a sample population to determine teachers' perceptions on the use of AI adaptive learning tools and the academic performance of senior secondary students. The descriptive survey enables the researchers to explore the extent to which these tools influence academic performance while identifying their benefits and challenges. Population of the study comprised of all science teachers in senior secondary schools in Minna Metropolis Niger State, Nigeria. Minna Metropolis consist of Bosso and Chanchaga LGAs with six hundred and eighty (680) science teachers. The population of the study is 680 Public Senior Secondary Schools Science Teachers in Minna Metropolis, Niger State. The sample randomly selected for this study are two hundred and forty (240) science teachers from the senior secondary schools which comprised of one hundred and fifty (150) male and ninety (90) female teachers using Krejcie and

Morgan table. The instrument for data collection was titled Teachers' Perceptions Use of AI Adaptive Learning Tools Questionnaire (TPUALTQ). The questionnaire contained fifteen 15 items and would be scored on a four-point rating scale of SA= Strongly Agree, A= Agree, SD= Strongly Disagree, D= Disagree. And the respondents are to select one option related to the response/item they believe is attainable. The instrument was validated by three (3) specialists in science education from Federal University of Technology Minna. Internal consistency reliability was established and the index was calculated using Cronbach Alpha formula and the index was found to be 0.80. Descriptive statistics was used to answer the research question and Mann-Whitney u-test was used to test the hypothesis with the aid of Statistical Product and Service Solution (SPSS) version 25 at 0.05 level of significant.

Results

Research Question One: What is the level of teachers' perceptions on use of AI adaptive learning tools in enhancing academic performance of secondary schools' students in Minna metropolis?

Table 1: Teachers' Perceptions on AI adaptive learning tools on academic performance of students in senior secondary schools

S/N	Items	N	Mean $\bar{x}$	Std. Dev.	Decision
1	The use of AI adaptive learning tools significantly enhances academic performance of students in virtual and practical skills	240	3.64	0.48	Positive Perception
2	Students gain hands-on experience through use of AI adaptive learning tools thereby improve their academic performance	240	3.60	0.58	Positive Perception
3	AI adaptive learning tools helps students develop critical thinking and problem-solving skills at varying learning pace	240	3.82	0.38	Positive Perception
4	AI adaptive learning tools bridges the gap between theoretical lessons and practical applications for students improved academic performance	240	3.33	0.85	Positive Perception
5	Students' concentration and learning abilities in academics increase when exposed to AI adaptive learning tools with good experiences and performance	240	3.62	0.49	Positive Perception
6	AI adaptive learning tools ease evaluation and assessment of students noting the areas of strength/weaknesses in academic performance	240	3.51	0.50	Positive Perception
7	Students show eagerness and enthusiasm in constructive skills when exposed to AI learning adaptive tools	240	3.56	0.50	Positive Perception
8	The use of AI adaptive learning tools broadly widens students' curiosity and knowledge in scientific concepts improving performance	240	3.51	0.59	Positive Perception

9	Students are motivated to learn at individual pace when using AI adaptive learning tools improving academic performance	240	3.50	0.59	Positive Perception
10	The interactive nature of AI adaptive learning tools increases students' desire to participate in science classes	240	3.37	0.48	Positive Perception
11	AI adaptive learning tools stimulate students' performance and feedback in science subjects	240	3.50	0.59	Positive Perception
12	Individual Student demonstrate improved practical skills after using AI adaptive learning tools	240	3.54	0.50	Positive Perception
13	AI adaptive learning tools positively impact students' pace overall academic performance and success in the science subjects	240	3.43	0.61	Positive Perception
14	The overall academic performance of students improves when evaluated and assess individually with the AI adaptive learning tools	240	3.42	0.58	Positive Perception
15	AI adaptive learning tools help students perform better in the science related subjects compared to conventional methods	240	3.20	0.75	Positive Perception
Grand Mean			3.50		
Standard Deviation				0.57	

Table 1 show the Mean ($\bar{x}$) and Standard Deviation (SD) of Teachers' Perceptions on AI adaptive learning tools on academic performance of senior secondary students. All items produced low mean scores below the benchmark of 2.5. The mean of 2.5 and above are those that agreed. The result presented in table above revealed that the respondents agreed that items 1□□ 14 and 15 respectively were accepted which indicates that there is Positive perception. The table has a grand mean ($\bar{x}$) of 3.50 and average standard deviation is 0.57 which implied that there is positive perception of teachers on impact of the use of AI adaptive learning tools for teaching and learning.

Research Question Two: What are the differences in male and female teachers' perceptions on the use of AI adaptive learning tools in enhancing academic performance of senior secondary school students.

Table 2: Mean and SD of Male and Female Teachers' Perceptions on the Use of AI Adaptive Learning Tools in Enhancing Academic Performance of Senior Secondary School Students.

Gender	N	Mean rank	Sum of Rank	Mean Rank Difference
Male	150	147.75	22162.50	72.67
Female	90	75.08	6757.50	

Table 2 show the Mean rank and sum of rank of Male and Female Teachers' Perceptions on AI adaptive learning tools in enhancing academic performance of senior secondary students. The result presented in table above revealed that male teachers had mean rank of 147.75 while female teachers had mean rank of 75.08. the mean rank difference is 72.67 indicating that there were differences in male and female teachers' perceptions on the use of AI adaptive learning tools in enhancing academic performance of senior secondary school students. The difference is in favour of male teachers.

Research Hypothesis

HO₁: there is no significant differences in male and female teachers' perceptions on the use of AI adaptive learning tools in enhancing academic performance of senior secondary school students.

Table 3 Mann Whitney U-test of gender differences in teachers in the ease of use of ai adaptive learning tools

Gender	N	Mean rank	Sum of Rank	U-test value	P-value
Male	150	147.75	22162.50	2662.50	0.09
Female	90	75.08	6757.50		

Table 3 above indicates the Mann Whitney statistic of the difference between male and female perceived ease of use of AI adaptive learning tools in secondary senior schools in Minna Metropolis. From the result, $U(150, 90) = 2662.50$, $P(0.09) 0.05$. This indicate that there is significant difference between male and female teachers perceived ease of use of AI adaptive learning tools. Hence, the hypothesis was rejected.

Discussion of the Findings

The findings of the study indicated that teachers' perceptions on AI adaptive learning tools in enhancing academic performance of students in senior secondary schools in Minna metropolis is positive. This finding is in agreement with the findings of Olanrewaju, (2023) who found that AI adaptive learning tools has impacted positively on the academic performance of students in secondary schools in south west Ibadan, Nigeria. The reason is quite similar to the findings of this study. This is why government at all levels should adopt the use of AI through Blended Learning strategy, such that AI complement and not replace the traditional teaching to preserve human interaction in teaching/ learning process in public secondary schools. Importantly, there should be training and retraining of teachers, government and stakeholders in education should provide capacity-building workshops for teachers to improve AI literacy. The study also indicate that male teachers have higher positive perception on the use of AI adaptive learning tools than female counterparts. And the difference was found to be significant. This finding concurs with the findings of Abidoye (2018) who reported that male teachers have higher positive perception on the use of AI adaptive learning tools than female counterparts.

Conclusion

Based on the findings of the study, it was concluded that teachers' perceptions on AI adaptive learning tools on academic performance of students in secondary schools in Minna metropolis, Niger State. Hence, AI adaptive learning tools significantly enhances individualized students'

academic performance and practical skills that enhance develop in them critical thinking and problem-solving skills. It was also concluded that gender has significant impact on science teachers' perceived ease of use of ai adaptive learning tools.

Recommendations

Based on the findings of this study, the researchers made the following recommendations:

1. On the job and or in-service training should be encouraged for teachers already in the service with limited AI knowledge, this training will enable the teachers to be up-to-date in AI literacy which can further assist them in blending pedagogy and AI adaptive tools for effective instructional delivery in the 21st century.
2. Stakeholders in education especially Government at the states and national levels should provide and equipped schools with reliable internet, electricity, and affordable digital devices/ ICT facilities that would encourage teaching/learning process for both the instructors and learners for optimum utilization in schools.
3. Policy makers and curriculum planners should integrate AI into secondary curricula and provide guidelines for implementation.
4. Periodic teachers' capacity building workshops, conferences and seminars should be organized for the teachers on the use of AI tools, multimedia and other virtual tools for instruction and guidance.

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EFFECT OF INTERACTIVE SIMULATIONS ON STUDENTS' ACHIEVEMENT AND CONCEPTUAL MASTERY IN CHEMISTRY IN SECONDARY SCHOOLS IN ABUJA MUNICIPAL AREA COUNCIL, FCT-ABUJA

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Abstract

Education is the foundation for personal growth and national development, and science education plays a vital role in building skills, values, and knowledge for a technology-driven world. Yet, Chemistry remains one of the most challenging subjects in Nigerian secondary schools due to its abstract nature, limited laboratory facilities, and reliance on traditional lecture methods that encourage rote memorization rather than deep understanding. This paper explores the potential of interactive simulations, particularly PhET, to address these challenges by making abstract concepts visual, engaging, and student-centered. Evidence from both local and international studies shows that simulations improve comprehension, conceptual mastery, retention, and academic achievement while boosting students' motivation and interest in STEM fields. Although barriers such as inadequate infrastructure and limited teacher training remain, these challenges can be overcome through strategic curriculum reform, professional development, and technology integration. The findings highlight the urgent need to adopt interactive simulations as a practical, affordable, and effective approach to improving Chemistry education in Nigeria.

Keywords: Chemistry, Interactive-simulation, PhET, Conceptual-Mastery, and Retention

Introduction

The primary goal of education is to facilitate knowledge transfer through learning activities that drive behavioral change, leading to desired outcomes while fostering holistic development in attitudes, skills, technological proficiency, and knowledge, since education serves as a tool for societal transformation and individual growth (Budhathoki, 2020). Nigeria's Post-Basic Education and Career Development (PBECD) policy (FRN, 2013) emphasizes self-improvement, equal opportunities for further education, and equipping students with sub-professional skills in applied sciences, teaching, and commerce, reflecting education's deliberate and systematic role in transmitting knowledge, values, and skills (Chazan, 2022). Science education, a dynamic field, enhances societal relevance through hands-on experiments, addressing challenges and supporting economic development, with teaching methods and pedagogical practices being crucial to its success (Sshana & Abulibdeh, 2020).

As an essential part of the curriculum, science education cultivates scientific literacy, process skills, and values, empowering students to thrive in a rapidly evolving society (Esu *et al.*, 2020). At the senior secondary school level, science education includes Biology, Chemistry, Physics, and Mathematics, with Chemistry being important for anyone who intends to pursue STEM related career (Usselman & Rocke, 2024). Despite the importance of Chemistry in fields like medicine, engineering, and food production, it is often perceived as a difficult subject because of its abstract concepts, and students struggle to link theory with real-world applications. Oyelekan (2016)

maintained that effective learning requires hands-on laboratory activities, yet many teachers rely on traditional lecture-based methods, which promote rote memorization over deep and conceptual understanding. This approach fails to cultivate critical thinking or problem-solving skills, leaving students ill-equipped to apply knowledge practically.

Kassaw and Demareva (2023) define academic achievement as the extent to which a student or instructor has met his/her educational objectives, often assessed through regular evaluations. It reflects the abilities acquired by individuals after the learning process, encompassing changes in knowledge, understanding, attitudes, and skills. It also serves as a key indicator of the success or failure of a learning process. Adopting interactive, student-centered teaching approaches is crucial for advancing science education in our knowledge-driven society. Therefore, Interactive simulations have the potential to enhance students' comprehension of complex concepts in Chemistry, and the integration of mastery learning models can simplify science concepts, leading to improved academic achievements and increase their likelihood of pursuing careers in science and technology.

Interactive simulations surpass traditional methods by offering immediate feedback, adapting to diverse learning styles, and creating student-centered environments. Technology-enhanced methods, particularly interactive simulations like VR and AR, offer transformative potential by converting abstract concepts into immersive, tangible experiences (Özeren & Top, 2023). These tools, ranging from web platforms to virtual laboratories leverage multimedia elements (sound, visuals, and real-time interaction) to make learning dynamic and accessible (Gambari *et al.*, 2016). One of the most widely used simulation platforms in science education is the Physics Education Technology (PhET) interactive simulations, developed by Nobel Laureate Carl Wieman at the University of Colorado.

PhET interactive platform enables students to visualize molecular structures, explore chemical reactions, and connect sub-microscopic, symbolic, and macroscopic concepts through game-like virtual experiments (Rahmawati *et al.*, 2022). The PhET platform has 166 simulations (including 53 chemistry-specific ones as of 2023), providing risk-free virtual labs where students manipulate variables and validate theories, accelerating conceptual understanding (Kizito & Hassan, 2024). By bridging the gap between abstract concepts and tangible experiences, PhET simulations address chemistry's inherent challenges while preparing students for advanced scientific study. Therefore, conceptual mastery in chemistry requires students to apply core ideas, predict chemical behavior, and translate between different representations skills enhanced by PhET simulations that visualize abstract processes (Palacios *et al.*, 2024). When integrated thoughtfully into inquiry-based activities, these simulations improve comprehension, retention, and academic achievement (Agu & Samuel, 2018).

Retention is the ability to retain and consequently remember things experienced or learned by an individual at a time. It takes place when learning is coded into memory. Retention is a product of meaningful learning when teaching is effective and meaningful to the students (Kamisah & Nur, 2013). However, the nature of the material to be coded are related to the quality of retention in terms of their meaningfulness, familiarity, concreteness and image-evolving characteristics. Thus, achieving conceptual mastery is critical for students' success in Chemistry and their overall

scientific literacy which will lead to positive academic achievement and the ability to retain the concepts learned.

However, despite the proven benefits of interactive simulation, its implementation in Nigerian secondary schools faces significant challenges. Two primary barriers that hinder widespread adoption may include inadequate technological infrastructure, including insufficient computers, projectors and unreliable internet connectivity (Oladejo & Ebisin, 2021), as well as critical shortage of teacher training in digital pedagogies. This study focuses specifically on secondary schools within Abuja Municipal Area Council (AMAC) of Nigeria's Federal Capital Territory (FCT), to examine how PhET interactive simulations, a globally recognized science education platform, can impact students' chemistry learning outcomes.

The Concept of Science Education

In science, students seek solutions to real-life problems, and the discipline of science education is concerned with discovering, developing, and evaluating methods and strategies to be used in teaching science effectively. Oyelekan (2016) defines science education as the process of transferring scientific knowledge, skills, and processes from one person to another. Every nation's growth reflects its scientific progress, and the scientific knowledge of subjects is essential for a nation to develop 21st-century technologies. This means that science literacy is necessary for human comfort, which calls for the necessity of scientific literacy in the Nigerian school with chemistry inclusive. Therefore, science education is essential as it is of immense value in the student's individual life and his life in society.

Since science affects almost every element of human life, science shapes cultural worldviews, conceptions, and thinking habits in many modern countries. Bancong and Song (2020) noted that one of the primary purposes of science education is to prepare students to think critically while solving problems rationally in a variety of ways and make judgments based on relevant information and facts obtained in the course of their study. Sari *et al.* (2020) posited that science learning environments should be arranged in a way that it can provide opportunities for students to explore and discover things by themselves. Therefore, if learning strategies and students' achievement in science have to improve, then the students have to be introduced to more, effective, efficient and appropriate teaching approaches (Jack, 2023^a).

Chemistry as a Science Subject at the Secondary School Level

Chemistry is one of the five branches of science, which is taught in secondary schools at the senior level is defined as the study of matter, what it is made of, how it behaves, its properties and how it changes during chemical reaction. Zhaobao and Xiaoling (2018), defined Chemistry as a fundamental natural science that investigates the composition, properties, structure and laws of change of substances and their applications at the atomic and molecular levels. Therefore, a significant fact about chemistry education is the understanding of interactions of elements and compounds, and the practical implications of these reactions in our daily lives. Thus, chemistry comprises theories, facts, and laws that have been explored and validated through rigorous experimental procedures.

The study of Chemistry helps students understand the world and produce a progressive society, to apply science concepts and principles to everyday concerns. Through the knowledge of chemistry,

many new substances have been created which have many important applications in our everyday lives, environment and activities, and every substance or object is related to chemical processes (Ahmad *et al.*, 2021). Lin (2023) noted that the difficulty of learning chemistry can be summarized by the inherent nature of science that makes it difficult to reach, and the limitations of traditional teaching. Hence, the advent of technology has profoundly impacted the field of chemistry education, from enhancing experimental accuracy to facilitating comprehensive mastery of complex concepts. Thus, in Nigeria, where access to fully equipped laboratories is limited, interactive simulations offer a cost-effective alternative to quality science education.

Traditional/Conventional Methods of Teaching Chemistry

Teaching is effective when the approach used brings about a desirable change in the behaviour of the learner. As noted by Alnaser and Forawi (2023), learning chemistry cannot be isolated from experiments, which requires mastering knowledge and discovery. However, the usual traditional laboratory experiments fall short of promoting learning and conceptual mastery of chemistry concepts and do not adequately support effective learning (Cooper and Stowe, 2018). Typically, the traditional methods of teaching focus on improving the communication of conceptual knowledge, learning abstract concepts, and using practical experiments to understand applications. This means that the type of teaching method and tools adopted by a teacher greatly impacts on students' concept mastery and understanding, interest and curiosity in learning chemistry and science related subjects in general.

Interactive Simulations in Science (Chemistry) Education

The use of technology in classrooms has been a subject of study in recent years, bringing about a shift in teaching methods and educational processes, as well as reforming curriculum to incorporate more technology integration (Siyam *et al.*, 2022). Following this present concern, a lot of teaching strategies and methods have been recommended by researchers for effective teaching and learning of chemistry. One of the promising methods is the use of interactive simulations, which provide an alternative avenue to traditional laboratory learning. Interactive simulations are virtual environments that mimic the scenario or functioning of a real-life system. Salame and Makki (2021) described simulations as computer-generated educational tools that can promote learning of concepts using simplified models of real-world phenomena through animation, visualization, and interactive learning experience, and observe outcomes in a controlled virtual environment.

Park (2019) noted that the use of technology tools like interactive simulations allows learners to participate in inquiry-based learning, which is a more student-centered approach, thus enhancing learners' representation of real-world scientific ideas. It is a method of teaching and learning for supporting knowledge acquisition, development of skill, test theories, and explore scenarios that may be impractical or impossible to study in real life (Lohmann, 2020). For example, chemistry simulations are designed to enhance students' understanding of complex chemical concepts virtually, by providing a visual and interactive learning experience and illuminating the principles of reactions without the risks associated with real-life experiments. They are also relevance in developing learners' cognitive knowledge (Ogebo & Ramnarain, 2024).

Physics Education Technology (PhET) Interactive Simulation in Chemistry Teaching

In environments where resources for teaching and learning of chemistry are limited, Physics Education Technology (PhET) simulation can be adopted, which is capable of extending learning beyond the classroom, as student can often access them remotely, enabling them to review and experiment with concepts independently at their own pace. PhET interactive simulation is a project at the University of Colorado (PhET, 2022), which provides an interactive fun way for learning science including chemistry. This software can be run online or downloaded through (<http://phet.colorado.edu>) for free. These simulations are highly interactive, animated and user-friendly, and creates a game-like environment to the students. They allow actions that explain and represent concepts, which would be impossible in the real-world setup. According to Mallory (2023) PhET simulations covers many science subjects like physics, chemistry, math, earth science and biology, with the current PhET website having 166 simulations available as of 2023, out of which 53 are chemistry related.

This therefore means that PhET interactive simulations provide a type of learning approach whereby students are involved in a guided inquiry-based learning activity through the analysis and interpretation of data (Yuliati *et al.*, 2018). It is designed to develop students' inquiry skills and it is made up of about hundreds of interactive simulations, found free to use. Physics Education Technology (PhET) is a widely recommended simulations for teaching and learning of sciences as an emerging strategy that students engage in scientific-like exploration, resulting in greater and deeper learning of scientific concepts through questioning, making connections, and deducing the rules. Omoy (2023) noted that PhET interactive simulation is a student-centered teaching strategy that enables students to fully engage in the learning process, just like they would when playing a video game.

Effect of PhET on Mastery of Chemistry Concepts and Academic Achievement

Conceptual mastery involves not only the memorization of facts or procedures of doing things, but understanding the underlying ideas that connect them, solve problems and adapt to new situations. According to Sausan *et al.* (2020), students' conceptual mastery of a range of chemistry topics could be improved by effective interactive simulations in chemistry in various settings. Conceptual mastery involves deep and meaningful understanding of the fundamental concepts, which is the higher-order thinking and development through manifold active intellectual engagement, aiming at meaning construction through pattern recognition and concept association between different topics in various contexts. These include inquiry, critical-thinking, creative thinking, problem-solving, and metacognitive skills.

Since the main purpose of teaching-learning process is to transfer knowledge to students and bring about behavioral change called learning outcomes or learning achievements. Thus, achieving conceptual mastery in Chemistry concepts is crucial for every student to be able to retain the concepts learned and their overall academic success. Salame and Makki (2021) in their study revealed that PhET interactive simulations have an overall positive impact to promote students' development of conceptual mastery of chemistry concepts and content, thereby facilitating furnishing learning opportunities and understanding abstract concepts that otherwise cannot be attained in a traditional laboratory setting. Diab *et al.* (2024) examined the impact of PhET simulations, and found that students who used the simulations did not just score higher on tests; also, did not just help students memorize facts, but showed a stronger ability to explain the

concepts behind their answers when solving problems and built a deeper understanding of scientific concepts.

Effect of PhET on Retention of Chemistry Concept and Academic Achievement

Retention is the ability to retain and consequently remember things experienced or learned by an individual at a time. It takes place when learning is coded into memory. Appropriate coding of incoming information provides the index that may be consulted so that retention takes place without an elaborate search in the memory lane. However, the nature of the material to be coded contributes to the level of retention. Materials are related to the quality of retention in terms of their meaningfulness, familiarity, concreteness, and image-evolving characteristics.

Nkosi *et al.* (2024) tested whether PhET interactive simulations could help students retain key chemistry concepts better than traditional teaching methods. Their results were clear that students who used the simulations not only understood the concepts better but also retained them for much longer. Also, Jack (2023^b) in their study revealed that students who were taught using computer simulations demonstrated significantly better long-term retention of the concepts compared to those who learned through traditional methods. The study concluded that using simulations is a highly effective teaching strategy, not only for helping students remember complex topics but also for improving their overall academic achievement in chemistry.

Conclusion

Chemistry is essential for students who aspire to careers in science, medicine, engineering, and technology, but the way it is currently taught often leaves learners discouraged and underprepared. This study has shown that interactive simulations, especially PhET, offer powerful solutions by bridging the gap between theory and practice. They enable students to visualize complex processes, test ideas safely in virtual labs, and retain knowledge more effectively than with traditional teaching methods alone. Research consistently supports their ability to enhance academic achievement, motivation, and long-term conceptual mastery. While infrastructure gaps and limited teacher readiness pose real challenges, these are not insurmountable. With the right policies and training, simulations can complement existing teaching methods and transform Chemistry education in Nigeria.

Recommendations

- i. PhET and similar tools should be formally included in the senior secondary Chemistry curriculum as a complement to laboratory work, and professional development programmes should be organized to equip teachers
- ii. Schools should be supported with affordable tools such as projectors, laptops, and offline versions of PhET to overcome connectivity issues.
- iii. Simulations should be used alongside practical labs where possible thereby, ensuring that students gain both conceptual understanding and hands-on skills.
- iv. Continuous studies should evaluate the impact of simulations on learning outcomes across different contexts and science subjects.

- v. Government and education stakeholders must create clear policies that support the adoption and scaling of interactive technologies in secondary schools.

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APPLICATION OF DIGITAL TOOLS AND HIGH TECHNOLOGICAL EQUIPMENT FOR IMPROVING TEACHING AND LEARNING OF METALWORK TECHNOLOGY IN TERTIARY INSTITUTIONS IN KADUNA STATE, NIGERIA

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Abstract

This study investigates the Application of Digital Tools and High Technological Equipment for Improving Teaching and Learning of Metalwork Technology in Tertiary Institutions in Nigeria. Three research questions guided the study, a descriptive survey research design was adopted for the study. The study was conducted in Kaduna state which covers three of the institutions namely Nuhu Bamalli Polytechnic Zaria, Kaduna Polytechnic and Kaduna State college of Education Gidan Waya, each covers one of the senatorial zones. The total of 100 respondents were used for the study, 25 lecturers/Technologists and 75 students. A 26 structured item questionnaire was designed by the researchers and validated by three experts, was used for data collection for the study. The questionnaire was administered randomly to staff and students. Four-point scale was used, Data collected were coded and analyzed on SPSS version 22 and presented in tables. Findings revealed that Digital Tools and High Technological Equipment for Improving Teaching and Learning of Metalwork Technology in Tertiary Institutions are lacking which most manufacturing processes are done manually and Nigeria indigenous business enterprises have failed to fully automate their activities because they lack the technological facilities and trained man power to utilize automated and computerized production systems. The recommendations are Institutions should invest in procuring modern equipment such as Computer Numerical Control machines and welding simulators. Government and private industries should fund digital learning infrastructure in tertiary institutions and technical college.

Keywords: Digital tools & High Technological Equipment, Teaching and Learning, Metalwork Technology.

Introduction

Metalwork trade is among the skilled subject studied in technical colleges, and it is a course offered by all mechanical engineering related trade students in tertiary institution and those studying metalwork technology itself or metallurgical engineering. Metalwork trade programme involve the application of basic scientific knowledge in the design, selection of materials, construction, operation of machines and fabrication of metal products. "It is a mechanical trade offered as general metalwork in Nigeria Technical Colleges", [Federal Republic of Nigeria (FRN 2013)]. Metalwork technology comprises the following areas of specialization which involves (welding, fabrication, machine operation, pattern making, forging etc.) is a core vocational/technical discipline in Nigerian tertiary education (Polytechnics, Colleges of Education Technical and Universities). The researchers view Metalwork technology as a major component of technical education that equips novice or learners with practical and applied skills in welding, machining, fabrication, foundry and forging, iron bending and design construction. Traditionally, metalwork

has been taught using manual tools and conventional machines. However, the rapid emergence of digital tools and high-technological equipment has transformed the way technical skills are taught and practiced globally. Adebayo & Oladipo (2021) says that “The Traditional teaching methods emphasize teacher demonstration and manual practice on conventional machines, on like the Advance in digital tools like (CAD/CAM, simulation software, virtual welding trainers, CNC programming environments) and HTE (CNC mills/routers, laser cutters, automated welding cells, Io T-enabled monitoring, industrial robots). Kalovrektis (2022) states that High digital technological equipment in education refers to advanced digital tools and systems, such as artificial intelligence (AI) Virtual Reality, Augmented Reality, and sophisticated learning management system that process data and enhance the communication Development, and exchange of knowledge to create more immersive, interactive, and engaging learning environments for students. These technologies move beyond basic electronics devices to offer more complex functions to support teaching and learning, and assessment in innovative ways.

These present opportunities to modernize pedagogy, increase safety, shorten learning curves, and better align graduates with industrial expectations for the twenty first century. Digital technology integration in education has grown to be a major worldwide trend that is changing how teachers present material and how students acquire knowledge. Globally, educational systems have adopted online platforms, interactive technologies, and digital resources to enhance instructional efficacy, learning outcomes, and student engagement. This shift is supported by emerging research emphasizing that digital pedagogues, when implemented with institutional support, promote personalized learning, collaborative engagement, and knowledge retention (Bond et al., 2021).

Digital tools such as Computer-Aided Design (CAD), Computer-Aided Manufacturing (CAM), simulation software, and virtual reality (VR), alongside high-technological equipment like Computer Numerical Control (CNC) machines, robotic welding arms, and laser cutters, provide opportunities for precision, safety, and enhanced creativity in teaching and learning of metalwork technology. Digital technologies have become an integral part of everyday life and also of teaching and learning in tertiary institution. Students of today, are often referred to as “digital natives” (Prensky, 2022), have grown up in the digital era, and as such commonly assumed to be expert users of digital technology, with these teaching and learning will easily be shifted toward what the generation are use and often engage with, which will make learning easier and skill acquisition simpler and interesting. Teaching and Learning process should be based on material organized around theoretical principles and experimentation and not on memorizing isolated elements and processes. Wang et al (2020) states that majority of teachers focus on how to succeed longer and deeper learning outcomes from their students by involving them to hands on activities. Education is learning, and a learning technique associated with the Fourth Industrial Revolution and focused on transforming the future of education through advanced technology and automation. The goal is to integrate technology into the curriculum, change the learning process and outcomes, leverage technology and enhance tertiary institution experience. Chicas et al (2020) states that the developments in the field of technology with artificial intelligence, machine learning, chatbots, unimaginable internet speeds, make it imperative that education adapts to these changes, in order to be able to follow the trend and the needs of students in this twenty first century, who are the workers of the future. There is a constant need for jobs in engineering and technology sector, and according to labor market studies, in the future, occupations that do not currently exist will have to be created, to meet the digital age and its demand. According to Psycharis and Kalovrektis

(2022) says that digital technologies and equipment like computer numerical control machines, welding simulators, laser cutters, robotic welding etc. are the main pillars to be considered when implementing a tool for effective means of teaching and learning in tertiary institutions.

Application of these high technological equipment is crucial in our institution of higher learning, as it influence students' motivation and learning outcomes, and adaptability to these new digital tools, will developed a high skilled for our graduate and demand for future Employability to meet the industrial skills of the century. If students view these technologies positively, they are more likely to embrace them and develop stronger technical competencies. However, in Nigeria, limited access to digital tools and high technological equipment in tertiary institutions. Raises concerns about how students perceive their role in improving practical learning of skills to meets the industrial needs of today's manufacturing trends and in the use of artificial intelligence.

Statements of the problem

Globally, industries are demanding technicians who are skilled in digital manufacturing and able to operate high technological equipment. Unfortunately, in Nigeria, most tertiary institutions still relied on outdated machines and equipment, and students have little or no exposure to advanced digital tools in manufacturing sector. This gap has raised questions about graduate from tertiary institution to adapt, to modern industrial practice for the world of works, which is one of the core objectives of technical education programme in Nigeria. Regrettably the performance of metalwork students appears unsatisfactory, as graduate of this programme cannot display their practical skills of metalwork trade with high technological equipment, Ogbuanya and Usoro (2019) noted that at graduation most students are deficient of Employability skills, work place skills, and job generation competencies. Egwu (2017) also asserted that, good technicians are difficult to come by in Nigeria, expatriates working in the country bring in their manpower from abroad due to dearth of competent skill personnel. As such many of the graduate drop their trade and engage in menial jobs to meet their daily needs and sometimes being engage in unskilled and social vices, constitute them as nuisance in their society, Hence the researchers saw the urgent need to awaken the latent creativity skills in millions of students, with progressive industrialization in the world of works, which this study determine, The Application of Digital Tools and High Technological Equipment for Improving Teaching and Learning of Metalwork Technology in Tertiary Institutions in Nigeria.

Purpose of the study

The purpose of this study is to determine the application of digital tools and high technological equipment for improving teaching and learning of metalwork technology in tertiary institutions in Nigeria. Specifically, the study sought to: -

1. Identify the availability of digital tools and high technological equipment in metalwork workshop in tertiary institution.
2. To what extent if adopted will improve the teaching and learning of metalwork technology in tertiary institution.

Research Questions

Two research questions guided the study -:

1. What is the availability of digital tools and high technological equipment in metalwork workshop in tertiary institution?

2. To what extent if adopted will improve the teaching and learning of metalwork technology in tertiary institution?

Methodology

The study adopted a descriptive survey research design to elicit information's from both Metalwork technology student of tertiary institution and Lecturers of metalwork technology. A total of 100 respondents participated in the study. The population of the study involves 75 Metalwork technology students of tertiary institution and 25 Lecturers/Technologists of metalwork technology. samples were drawn using random sampling technique, sampled from three tertiary institutions in Kaduna state, (Kaduna polytechnic, Nuhu Bamali polytechnic Zaria and Kaduna state college of Education Gidan waya, each from the senatorial zones). The researchers developed a well-structured questionnaire as an instrument for data collection. Three experts from the department of Industrial and Technology Education Federal University of Technology Minna had a facial content validity for relevance and structure. The internal consistency of the study was conducted using Cronbach Alpha formula and a reliability co efficient obtained 0.82. The instrument for data collection was the Application of digital tools and high technological equipment structured questionnaire that addresses the research questions. The researchers distributed the questionnaire with the help of two (2) research assistants to the respondent in their respective institutions. The researchers used the response code of four-point scale, Research question 1 Available and Functional (AF), Available not Functional (ANF), Neutral (N), Not Available (NA), and Research question 2 has strongly Agree (SA), Agree (A), Disagree (DA) and strongly Disagree (SD), in design of the instruments which contained 26 items, of two different sections. The result of the study was analysed using mean statistics. An item with the mean score of 3.00 and above is agreed by student of tertiary institution studying metalwork technology and lecturers in tertiary institutions.

Discussion of the findings

Research Question 1.

What is the availability of digital tools and high technological equipment in metalwork workshop in tertiary institution?

Table 1: Mean responses on the availability of digital tools and high technological equipment in metalwork workshop

S/N	ITEMS	Mean	Remarks
1	Computer Numerical Control (CNC) lathe machines are available.	3.00	Agreed
2	CNC milling machines are available for teaching and learning in my institution.	3.50	Agreed
3	Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) software are accessible for use.	3.50	Agreed
4	3D printing machines are available in the metalwork workshop.	3.00	Agreed

5	Laser cutting machines are available for practical training.	3.00	Agreed
6	Plasma arc cutting machines are accessible in the workshop.	3.40	Agreed
7	Welding simulators are available for student training.	3.00	Agreed
8	Robotic equipment is available for welding and fabrication processes.	3.50	Agreed
9	Digital measuring instruments (e.g., digital calipers, Coordinate Measuring Machine) are available for use.	3.00	Agreed
10	Augmented Reality (AR) tools are available for metalwork training.	3.00	Agreed
11	Virtual Reality (VR) tools are available for metalwork training.	3.50	Agreed
12	My institution regularly upgrades or acquires modern digital equipment for metalwork technology.	3.50	Agreed
13	Digital technological equipment available in my institution meets current industrial needs.	3.00	Agreed

Table 1 shows that 13 items of the availability of digital tools and high technological equipment present in metalwork workshop in tertiary institution had their mean from 3.00 and above were agreed by both Lecturers/Technologist and student offering metalwork Technology in tertiary institution in Kaduna State Nigeria.

Research Question 2.

To what extent if adopted will improve the teaching and learning of metalwork technology in tertiary institution?

Table 2: Mean responses of the digital tools and high technological equipment if adopted will improve the teaching and learning of metalwork technology in tertiary institutions.

S/N	ITEMS	Mean	Remarks
1	Adoption of high digital technological equipment will enhance practical skill acquisition in metalwork technology.	3.00	Agreed
2	Digital technologies will improve accuracy and precision in metalwork operations.	3.00	Agreed
3	Using CNC machines, CAD/CAM software, and welding simulators will increase student engagement and interest.	3.50	Agreed

4	Adoption of 3D printing and robotics will improve curriculum delivery in metalwork technology.	3.00	Agreed
5	Exposure to advanced digital tools will better prepare students for industry standards.	3.00	Agreed
6	Augmented reality (AR) will promote problem-solving and creativity among students.	3.00	Agreed
7	Adoption of Visual reality (VR) will promote problem-solving and creativity among students.	3.50	Agreed
8	Digital equipment will speed up training and make learning more efficient.	3.00	Agreed
9	High-tech equipment improves accuracy and efficiency in practical learning.	3.00	Agreed
10	Using simulators and CAD reduces material wastage during skills training for better learning.	3.00	Agreed
11	Exposure to modern tools increases my confidence in handling industrial jobs because of the operational knowledge and skills I acquired.	3.50	Agreed
12	Digital tools when adopted will help student understand theoretical concepts better, with less stress.	3.00	Agreed
13	I believe digital technologies prepare me better for future employment with confidence into the world of works.	3.00	Agreed

Table 2 shows that, the 13 items were agreed, because the mean score is 3.00 and above, as to what extent if digital tools and high technological equipment if adopted will improve the teaching and learning of metalwork technology in tertiary institution.

Discussion of the Findings

The findings of this study presented in table 1, revealed that Computer Numerical Control (CNC) lathe machines are available in the metalwork workshop, CNC milling machines are available for teaching and learning in my institution, Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) software are accessible for use, 3D printing machines are available in the metalwork workshop, Welding simulators are available for student training, Digital measuring instruments (e.g., digital calipers, Coordinate Measuring Machine) are available for use, Virtual Reality (VR) or Augmented Reality (AR) tools are available for metalwork training, The availability of digital technological equipment in my institution meets current industrial needs. All these equipment is lacking in our workshops which is in agreements with, Shrestha (2020) states that the future of education system will be enabled by a collection of emerging digital technologies, which will create ubiquitous, immersive, adaptive and personalized learning experience, Remote access lab prototypes are vital for the education of future engineers that will help in modern

manufacturing in engineering fields. Whereas most of the digital and high technological machines are absent in our workshops. Which is in consonant with Okwori (2017) which says Inadequate equipment and instructional materials, shortage of facilities and equipment, which create gaps between theory and practice, skills the present system is providing for graduate is theoretical and the emphasis in our country is on certification rather than acquisition of skills that is functional and will make them self-reliant, Mike (2011) in Okwori (2017) which states that Nigeria technological growth is behind that of industrialized nations, most manufacturing processes are done manually and most business enterprises have failed to fully automate their activities because of lack of technological facilities and trained man power to utilize automated and computerized production systems. The poor state of Nigeria's technology has led to high cost of production and poor-quality output of Nigeria's industrial products.

The findings for research question 2 shows that 13 items were agreed by the respondent which is Adoption of digital tools and high technological equipment will enhance practical skill acquisition in metalwork technology, Using CNC machines, CAD/CAM software, and welding simulators will increase student engagement and interest, Adoption of 3D printing and robotics will improve curriculum delivery in metalwork technology, Digital equipment will speed up training and make learning more efficient which is in consonant with Lund & Aagaard, (2020) states that digital tools could be used to support teaching and learning, which may encourage transformative digital agency and engagement with the new digital technology. Wirani et al., (2022) which says these digital tools are successful in enriching the learning experience and fostering active involvement among students and were helpful increasing knowledge and confidence. The opinion of authors above help to justify the findings of this study.

Conclusion

By definition, all students are “digital natives” in the sense that they have grown up in digital era. However, students today are heterogeneous group as regards to their attitudes toward the use of digital tools and Technology in education. Digital tools and High Technological Equipment have strong potential to enhance teaching and learning of metalwork technology, improving safety, skill acquisition, and alignment with industrial needs. However, adoption in Nigerian tertiary institutions faces practical constraints that must be addressed through coordinated policy, funding, and capacity building, because Students recognize the importance of digital tools and high technological equipment in improving metalwork practical learning. However, their limited access to these technologies reduces the effectiveness of their training.

Recommendations

1. Institutions should invest in procuring modern equipment such as Computer Numerical Control machines and welding simulators.
2. Government and private industries should fund digital learning infrastructure in tertiary institutions and technical colleges.
3. Teachers Training: regular professional development and certification programs in CAD/CAM, CNC programming, and simulator-based pedagogy, and teachers should receive training on integrating digital tools and high technological equipment into teaching and learning process.
4. Students should be given more opportunities for hands-on practice using advanced tools to meets industrial demands.

5. Policy makers should revisit the curricula to reflect the use of digital tools and modern Industrial technologies.
6. Public–Private Partnerships (PPP): partner with industry for equipment donations, internships, and curriculum co-design.

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SMART VERSUS CONVENTIONAL SCHOOLING: IMPLICATIONS FOR STUDENT OUTCOMES, ENGAGEMENT AND POLICY REFORM IN NIGERIA

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Abstract

Smart and conventional schools represent two distinct approaches to education, each shaping learning experiences in unique ways. Smart schools leverage digital technologies, interactive platforms and adaptive teaching strategies to enhance student engagement, motivation and academic achievement. In contrast, conventional schools rely on structured routines, teacher-led instruction and established disciplinary practices, providing stability and accessibility, especially in resource-limited contexts. While smart schools offer innovation and interactivity, they face challenges related to equity, teacher preparedness and infrastructure. Conventional schools, though less dynamic, maintain reliable attendance and foundational skills. Integrating the strengths of both models through hybrid approaches, supported by teacher training, curriculum redesign and targeted infrastructure investment, can promote inclusive, engaging and sustainable learning environments that meet diverse student needs.

Keywords: Accessibility, Attendance, Conventional schools, Digital divide, Engagement, Inclusion, Policy reform, Smart schools and Student outcomes

Introduction

The conversation around smart schools in Nigeria has grown louder in recent years, reflecting a broader global trend of using technology to reimagine classrooms. Chukwuemeka, Dominic, Akanbi and Aregbesola (2025) highlighted how this shift from traditional schooling towards smart learning is filled with both promises and pitfalls. They argue that while digital platforms and interactive tools create new opportunities for collaboration, accessibility and personalized instruction, the transition is not straightforward. Teachers, students and policymakers all face the pressing question: how can this innovation be adapted to the Nigerian context without leaving sections of learners behind?

Smart education does not exist in a vacuum it requires carefully designed frameworks that enable smooth integration into existing systems. Adenubi *et al.* (2025) stressed that introducing technology into basic schools must be guided by deliberate planning. Their proposed Digital Framework for Technology Integration in Education (DIFTIE) reflects a recognition that without structure, technology becomes ornamental rather than transformative. This perspective matters because Nigerian schools operate under uneven resource distribution and without deliberate frameworks, the smart-conventional divide could deepen educational inequalities instead of bridging them.

However, evidence suggests that embedding smart technologies into Nigerian classrooms has not been without challenges. Karofi (2025) noted persistent barriers in colleges of education, including infrastructure gaps, digital illiteracy and resistance from stakeholders unprepared for new

approaches. Oshowole (2024) also observed that even at the primary level in Lagos, classroom technology faces hurdles such as unreliable power, insufficient funding and inadequate teacher training. These studies show why comparisons between smart and conventional schools are crucial: understanding their differences can inform balanced reforms, ensuring that policy choices align with realities on the ground rather than idealised visions.

Concepts of smart and conventional schooling system

Smart school

A smart school can be described as a learning environment that actively integrates digital technologies, adaptive teaching strategies and innovative management practices to enhance student learning and engagement. Mogas *et al.* (2022) emphasize that in the era of the fourth industrial revolution, school leaders view smart schools as future-oriented spaces that align education with technological and societal changes. Mangione and Cannella (2021) add that smart schools are not limited to urban centres; they can also empower remote communities through digital platforms and distance education, making learning accessible where physical resources are scarce. Lee and Lee (2024) remind us that teachers remain central to the success of smart schools, acting as adaptive agents who transform technology-driven reforms into meaningful classroom practices that benefit learners.

Conventional school

Conventional schools are widely recognised as the traditional model of education, built on structured classrooms, fixed timetables and teacher-led instruction aimed at shaping both knowledge and character. Nasution (2024) highlights their role in children's moral and social development, contrasting this with alternative systems such as homeschooling. Morrison (2024) offers a critique, noting that conventional education often requires “unlearning” entrenched practices when families transition to more democratic school models, suggesting its limitations in fostering autonomy. Yet, Onyinyechukwu (2021) argues that conventional schools remain adaptable, as shown in efforts to integrate Montessori approaches to meet the needs of 21st-century learners. Similarly, Al-Said *et al.* (2023) find that conventional settings can balance traditional and digital methods, making them resilient institutions that continue to evolve within changing educational landscapes.

Global and Nigerian trends in educational innovation

Educational innovation has become a defining theme in both global and Nigerian contexts, reshaping how knowledge is delivered and consumed. Nwabueze and Isilebo (2022) note that internationally, modern trends emphasise learner-centred approaches, technology integration and cross-cultural perspectives that make education more inclusive. Uzundu (2021) situates Africa within this shift, stressing advances in communication technologies that open new avenues for teaching and collaboration. In Nigeria, Oyinlola *et al.* (2024) highlight how universities are adopting entrepreneurial and innovative practices despite challenges of funding and infrastructure. Similarly, Abubakar (2021) points to library and information science education adapting to the digital age, reflecting broader systemic change. Adeniyi *et al.* (2024) argue that educational reforms across Africa, including Nigeria, increasingly prioritise performance outcomes, signalling a shift towards accountability and sustainable innovation.

Educational innovation in Northern Nigeria reflects both creativity and constraint, shaped by unique regional realities. Oyinola *et al.* (2024) show how universities nationwide, including those in the North, are embracing entrepreneurship and innovative practices to enhance relevance and employability. Wakil *et al.* (2024) highlight how new IT trends are gradually transforming classrooms, offering fresh opportunities for teaching and learning despite infrastructural gaps. Yet, challenges remain: Kanu *et al.* (2024) reveal that insecurity in the Northwest disrupts access to education, limiting innovation's reach. Malah and Sassi (2024) add that comparative insights with Niger underscore the need for context-specific solutions to sustain progress.

4. Review of Smart and Conventional School Studies

Year	Author(s) and Study	Location/Area	Methodology / Sample	Findings / Results
2021	Mangione and Cannella (Smart)	Remote schools, Italy	Case study of small schools using distance education	Smart schools in remote areas leveraged distance education to overcome isolation and improve access.
	Onyinyechukwu (Conventional)	Nigeria	Qualitative study on Montessori adoption in conventional schools	Conventional schools can adapt Montessori methods to better prepare 21st-century learners.
	Qureshi <i>et al.</i> (Smart)	Pakistan	IoT-based system for school monitoring	IoT applications enhanced school security and resource management.
	Eyuboglu <i>et al.</i> (Conventional)	Turkey	Quantitative survey on bullying prevalence	Traditional schools reported high bullying rates, with links to mental health concerns.
2022	Mogas <i>et al.</i> (Smart)	Catalonia, Spain	Qualitative interviews with principals	Principals viewed smart schools as aligning with Industry 4.0, but requiring leadership adaptation.
	Zeeshan <i>et al.</i> (Smart)	Global	Literature review	IoT promotes sustainable smart education but faces infrastructure challenges.
	Sins <i>et al.</i> (Conventional)	Netherlands	Comparative study between Dalton and	Alternative models outperformed traditional schools on student engagement and learning outcomes.

Year	Author(s) and Study	Location/Area	Methodology / Sample	Findings / Results
2023	Mann <i>et al.</i> (Conventional)	Global	traditional schools Systematic review	Outdoor learning enhances development more effectively than conventional indoor approaches.
	Wahyudin <i>et al.</i> (Smart)	Lampung, Indonesia	Case study at Islamic vocational school	Smart schools improved quality of teaching and services.
	Badshah <i>et al.</i> (Smart)	Global	Survey of IoT in education	IoT identified as central to smart education but hindered by cost/security.
2024	Al-Said <i>et al.</i> (Conventional)	Russia	Teacher assessment survey	Teachers noted resilience when blending traditional and digital education.
	Zaini and Hamidah (Conventional)	Indonesia	Qualitative study on santri values	Traditional schools transform cultural values even in digital contexts.
	Lee and Lee (Smart)	South Korea (Smart city schools)	Case study of teachers as agents of change	Teachers adapt to technology reforms, shaping smart school success.
	Yusup and Ahmad (Smart)	Indonesia	IoT-based smart learning implementation in a secondary school	Smart school system improved interactivity and efficiency of teaching.
	Nasution (Conventional)	Indonesia	Comparative review of schooling vs. homeschooling	Conventional schools contribute significantly to character formation.
	Morrison (Conventional)	UK (Free School)	Ethnographic study	Transitioning away from conventional schooling required “deep unlearning” of rigid norms.
2025	Chukwuemeka <i>et al.</i> (Smart)	Nigeria	Literature-based study on transition to smart education	Highlighted opportunities for smart learning but stressed challenges in equity and readiness.

Year	Author(s) and Study	Location/Area	Methodology / Sample	Findings / Results
	Karofi (Smart)	North-Eastern Nigeria	Qualitative study in colleges of education	Barriers included poor infrastructure, training gaps and resistance to change.
	Arias-Ortega and Previl (Conventional)	Chile	Perspectives of traditional Mapuche educators	Conventional schools must integrate indigenous knowledge for intercultural effectiveness.
	Bunnell and Gardner-McTaggart (Conventional)	Global elite schools	Qualitative leadership study	Conventional elite schools maintain cultural capital and hierarchical leadership norms.

Smart and conventional school student's outcome and engagement

Smart schools hold the potential to transform student outcomes by fostering active learning, creativity and deeper engagement. Darling-Hammond *et al.* (2024) emphasise that redesigned schools, when infused with digital tools and collaborative practices, can drive academic motivation and improve long-term achievement. Nichols (2022) similarly argues that building innovation schools requires infrastructures that centre equity, ensuring that digital advancements reach all learners rather than only the privileged few. Evidence from Ghana by Adarkwah *et al.* (2024) further illustrates how instructors in smart classrooms report higher levels of interactivity, collaboration and student enthusiasm compared with traditional, “hard teaching” environments. These accounts highlight the motivational benefits of smart schooling when technology is thoughtfully integrated into pedagogy.

Yet, the shift towards smart education is not without its gaps and challenges. Chari (2024) underscores how socio-economic disparities still limit access to the devices, internet connectivity and supportive environments necessary for technology-driven learning. Oshowole (2024) provides a Nigerian perspective, pointing out barriers such as inadequate infrastructure, limited teacher readiness and unreliable power supply, which reduce the effectiveness of smart school initiatives. Without addressing these structural issues, the advantages of smart schools risk deepening existing inequities.

By contrast, conventional schools, though less innovative, continue to offer strengths that should not be overlooked. Their emphasis on discipline, routine and accessibility provides a sense of stability that supports large populations of learners, especially in resource-constrained contexts. While smart schools promise engagement and creativity, conventional schools maintain structures that are often more sustainable in challenging environments.

Attendance and inclusion in smart and conventional schools

Attendance patterns often reveal the hidden inequalities between smart and conventional schools. Smart schools, with their emphasis on technology-enhanced learning, can foster higher attendance by making lessons more engaging and interactive, motivating students to participate regularly.

However, these gains are uneven. Tripathi (2024) observes that socio-economic disparities influence who can consistently access smart learning environments, as students without stable internet or digital devices are at risk of disengagement and irregular attendance. In contrast, conventional schools, though less innovative, offer more predictable access, since their learning processes do not depend heavily on technology. This accessibility can make attendance more reliable for students from lower-income households.

The digital divide plays a central role in shaping patterns of inclusion. Memon and Memon (2025) argue that without deliberate policy intervention, digitalisation risks excluding disadvantaged learners, particularly in low-resource contexts where electricity and connectivity remain unreliable. Chari (2024) further stresses that technology-driven schooling can inadvertently reinforce existing socio-economic divides, with wealthier students reaping the benefits of digital tools while poorer peers face compounded disadvantages. From an international perspective, Gottschalk and Weise (2023) highlight that even in OECD countries, equity concerns persist, suggesting that policy reforms must prioritise inclusion if digital schooling is to be transformative. For Nigeria, the lesson is clear: expanding smart schools requires policies that guarantee equitable access. This includes subsidising digital infrastructure for disadvantaged communities, training teachers in inclusive practices and safeguarding attendance by ensuring that socio-economic background does not determine who benefits from educational innovation.

Conclusion

Smart and conventional schools both offer valuable insights for shaping the future of education. While smart schools enhance achievement, motivation and inclusion through technology, conventional schools provide discipline, structure and accessibility. Balancing these strengths calls for hybrid approaches that integrate innovation without neglecting equity. With effective policies, teacher readiness and infrastructure support, education systems can create more inclusive, engaging and resilient environments that meet the diverse needs of learners.

Recommendations

1. Policymakers should promote hybrid schooling that blends smart and conventional strengths.
2. Teacher training must prioritise digital competence and inclusive practice.
3. Curricula need redesign to align with emerging educational innovations.
4. Sustained investment in infrastructure is vital for equity and access.

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AWARENESS AND ADOPTION OF ARTIFICIAL INTELLIGENCE AS A TOOL FOR IMPROVING INSTRUCTIONAL DELIVERY METHODS AMONG WOODWORK TECHNOLOGY TEACHERS IN HIGHER INSTITUTIONS IN NORTH-CENTRAL, NIGERIA

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Abstract

The study investigated the extent of awareness and adoption of Artificial Intelligence (AI) as a tool for improving instructional delivery methods among woodwork teachers in higher institutions in North-central, Nigeria. Two research questions and two null hypotheses guided the study. Descriptive survey design was adopted for the study. The targeted population of the study was 105 respondents comprising of 41 highly experienced and 64 moderately experienced wood technology teachers from seven higher institutions in North-central, Nigeria. A structured questionnaire titled: “Awareness and Adoption of Artificial Intelligence Tools for Instructional Delivery Questionnaire (AAAITIDQ)” with 28 items was designed and used for data collection by the researcher. The instrument was subjected to both face validation by three experts in the Department of Industrial and Technology Education, Federal University of Technology, Minna, Niger State. To ascertain the reliability of the validated instruments, a pilot study was conducted by administering the validated questionnaire to three highly experienced and two moderately experienced wood technology teachers in Benue State University. Cronbach Alpha’s statistical technique was used to determine the internal consistency of the instrument which yielded an overall reliability coefficient of 0.87 indicating that the instrument was reliable and suitable for use. Mean and standard deviation were used to answer the research questions. Data collected were coded and analyzed using the Statistical Package for Social Sciences (SPSS, Version 27). Based on the analyses, the findings of the study revealed that the extent of awareness of AI as a tool for improving instructional delivery methods among wood technology teachers in higher institutions was high with the grand mean of $\bar{X} = 3.65$. The study also revealed that the extent of adoption of AI as a tool for improving instructional delivery among wood technology teachers in higher institutions was low with the grand mean of $\bar{X} = 2.63$. Based on the findings, it was recommended among others that targeted training programmes and workshops should be organized to equip wood technology teachers with practical skills for effectively integrating AI into lesson planning, teaching aids, assessments, and performance tracking.

Keywords: Awareness, Adoption, Artificial Intelligence, Improving Instructional Delivery Methods, Woodwork Technology Teachers, Higher Institutions

Introduction

The rapid advancement of technology in the 21st century has significantly transformed the educational landscape. Among these innovations, Artificial Intelligence (AI) has emerged as one of the most influential tools for reshaping instructional delivery, research, and assessment in higher institutions worldwide (Luckin *et al.*, 2016). AI refers to computer systems designed to perform tasks that typically require human intelligence, such as problem solving, decision making, and

learning (Russell & Norvig, 2021). In education, AI has been increasingly applied in personalized learning, intelligent tutoring systems, automated grading, content generation, plagiarism detection, and predictive analytics, thereby improving teaching and learning processes (Holmes *et al.*, 2019). Higher institutions are under pressure to improve the quality of instructional delivery to meet the demands of globalization, industry expectations, and 21st-century skills (Olanrewaju, 2020). Woodwork, as a component of technical and vocational education, requires innovative pedagogical methods that enhance both theoretical knowledge and practical skills. However, traditional teaching methods often limit individualized learning, efficiency, and the integration of digital tools that can support students' creativity and problem-solving abilities (Ogbuanya & Owodunni, 2015). Integrating AI into woodwork instruction offers opportunities to address these gaps by supporting simulation of woodworking processes, providing digital design assistance, and facilitating more effective assessment practices (Baker & Smith, 2019).

Awareness and adoption of AI among teachers are critical factors in realizing these benefits. Awareness relates to teachers' knowledge of AI tools, their functions, and their potential application in the classroom, while adoption refers to the extent to which teachers integrate these tools into their teaching practices (Venkatesh *et al.*, 2003). Studies in developed countries reveal that many educators are increasingly aware of AI and adopt it in their teaching practices (Zawacki-Richter *et al.*, 2019). However, in developing contexts such as Nigeria, low awareness, inadequate infrastructure, and limited professional training have hindered effective adoption of AI in higher education (Afolabi & Oyediran, 2022). For woodwork teachers in higher institutions in North-central, Nigeria, the situation is particularly crucial. The region is home to several universities, polytechnics, and colleges of education that train future technical educators and skilled artisans. If teachers in these institutions lack awareness or fail to adopt AI tools, students may be deprived of opportunities to acquire relevant digital competencies and industry-aligned skills. Conversely, greater awareness and adoption of AI could lead to more engaging instructional delivery methods, enhanced student learning outcomes, and improved competitiveness of Nigerian graduates in the global knowledge economy. Given this, it became necessary for this study to investigate the extent of awareness and adoption of AI as a tool for improving instructional delivery methods among woodwork teachers in higher institutions in North-central, Nigeria.

Statement of the Problem

The integration of AI into education has been recognized globally as a pathway to enhancing teaching and learning effectiveness, improving student engagement, and equipping learners with 21st-century skills (Holmes *et al.*, 2019; Luckin *et al.*, 2016). In technical and vocational education, particularly woodwork instruction, AI can provide valuable tools for lesson planning, instructional simulation, assessment, and feedback.

Despite these potentials, many higher institutions in Nigeria still rely heavily on traditional teaching methods that limit the flexibility, efficiency and personalization of instruction (Ogbuanya & Owodunni, 2015). Afolabi and Oyediran (2022) reported that the awareness and adoption of AI among lecturers in Nigerian higher institutions is still low, with limited access to training, poor infrastructural support, and minimal institutional encouragement being major constraints. Consequently, woodwork teachers, who play a crucial role in training skilled manpower for national development, may not be taking advantage of AI tools to enhance instructional delivery. This gap raises concerns about the readiness of graduates from higher institutions in North-central,

Nigeria to compete in a knowledge-driven global economy where AI competence is becoming indispensable.

Although research on AI in education is expanding globally (Zawacki-Richter *et al.*, 2019), there is limited empirical evidence focusing on technical and vocational subjects such as woodwork in Nigeria. The extent to which woodwork teachers in higher institutions in North-Central Nigeria are aware of AI applications and the degree to which they adopt them in instructional delivery remain largely unknown. Without such knowledge, it will be difficult for policymakers, educational leaders, and curriculum developers to design effective strategies that promote AI integration in technical education. It is against this backdrop that this study sought to determine the extent of awareness and adoption of AI as a tool for improving instructional delivery methods among woodwork teachers in higher institutions in North-central, Nigeria.

Aim and Objectives of the Study

The aim of the study was to examine woodwork technology teacher's awareness and adoption of AI as a tool for improving instructional delivery methods in higher institutions in North-central, Nigeria. Specifically, the objectives were to:

1. determine the extent of awareness of AI as a tool for improving instructional delivery methods among wood technology teachers in higher institutions in North-central, Nigeria.
2. determine the extent of adoption of AI as a tool for improving instructional delivery methods among wood technology teachers in higher institutions in North-central, Nigeria.

Research Questions

Based on the objectives of the study, the following research questions guided the study:

1. What is the extent of awareness of AI as a tool for improving instructional delivery methods among wood technology teachers in higher institutions in North-central, Nigeria?
2. What is the extent of adoption of AI as a tool for improving instructional delivery methods among wood technology teachers in higher institutions in North-central, Nigeria?

Methodology

A descriptive survey research design was adopted for the study. This design was deemed appropriate because it facilitates the systematic collection of data from a defined population through the use of structured questionnaires, and permits the researcher to describe, analyze and generalize findings to the larger population (Fraenkel, *et al.*, 2019). The targeted population of the study was 105 respondents comprising of 41 highly experienced and 64 moderately experienced wood technology teachers from seven higher institutions in North-central, Nigeria. The instrument for data collection structured questionnaire titled: "Awareness and Adoption of Artificial Intelligence Tools for Instructional Delivery Questionnaire (AAAITIDQ)". The instrument was a 28 items questionnaire designed by the researcher. Responses were structured on a four-point Likert scale of: High Extent (HE), Moderate Extent (ME), Low Extent (LE), and Very Low Extent (VLE) with numerical values of 4, 3, 2, and 1 respectively. The instrument was subjected to both face validation by three experts. To ascertain the reliability of the validated instruments, a pilot study was conducted by administering the validated questionnaire (AAAITIDQ) to three (3) highly experienced and two (2) moderately experienced wood technology teachers in Benue State University, in Benue State. Cronbach Alpha's statistical technique was used to determine the internal consistency of the instrument which yielded an overall reliability coefficient of 0.87

indicating that the instrument was reliable and suitable for use. The data collected was analyzed using mean and standard deviation. Mean and standard deviation were used to answer the research questions.

Research Question 1: What is the extent of awareness of AI as a tool for improving instructional delivery among wood technology teachers in higher institutions in North-central, Nigeria?

The data for answering research question 1 is presented in Table 1.

Table 1: Mean and Standard Deviation of Respondents on the Extent of Awareness of AI as a Tool for Improving Instructional Delivery Methods among Wood Technology Teachers

S/N	Statement	Mean ($\bar{x}$)	SD	Remark
		(N = 105)		
1	I am aware that AI tools can be used to prepare lesson plans in woodwork instruction	3.85	0.45	HE
2	I know that AI can create or simulate woodworking designs for teaching purposes	3.73	0.48	HE
3	I am aware that AI can generate teaching aids such as diagrams, videos, or interactive materials.	3.83	0.50	HE
4	I am aware that AI can assist in assessing students' practical and theoretical woodwork skills.	3.74	0.52	HE
5	I know that AI tools can support personalized learning for students in wood technology courses.	3.70	0.55	HE
6	I am aware of AI-powered plagiarism detection tools for checking student assignments	3.40	0.60	ME
7	I know that AI can facilitate virtual simulations of woodworking processes	3.35	0.62	ME
8	I am aware that AI can assist in tracking student progress and performance analytics	3.68	0.49	HE
9	I know about AI-based platforms that can enhance teaching and learning efficiency in woodwork	3.80	0.47	HE
10	I am aware of the potential of AI to improve instructional delivery in higher institutions	3.72	0.51	HE
11	I am aware that AI tools can help create interactive quizzes and assessments for woodwork students	3.65	0.53	HE
12	I know that AI can be used to provide feedback to students automatically on practical exercises	3.60	0.50	HE
13	I am aware that AI can assist in scheduling and organizing instructional activities efficiently	3.55	0.54	HE
Grand Mean/SD		3.65	0.52	High Extent

Note: N = Number of Respondents; SD = Standard Deviation; VHE = Very High Level

Table 1 shows the mean responses of the respondents on 13 items posed to determine the extent of awareness of AI as a tool for improving instructional delivery methods among wood technology teachers in higher institutions in North-central, Nigeria. The mean values of the respondents ranged from 3.35 to 3.85, with a resulting grand mean of 3.65, which implies that the respondents collectively rated the items at a high extent, with a few items at moderate extent, as indicators of their awareness of AI as a tool for improving instructional delivery. Also, the standard deviation

of the items ranged from 0.45 to 0.62, with a resulting average standard deviation of 0.52, which indicates that the 13 items had standard deviations less than 1.96, showing that the respondents' ratings were not too far from the mean and were close to one another in their responses. This closeness of the responses adds value to the reliability of the mean.

Research Question 2: What is the extent of adoption of AI as a tool for improving instructional delivery methods among wood technology teachers in higher institutions in North-central, Nigeria?

The data for answering research question 2 is presented in Table 2.

Table 2: Mean and Standard Deviation of Respondents on the Extent of Adoption of AI as a Tool for Improving Instructional Delivery Methods among Wood Technology Teachers

S/N	Statement	Mean ($\bar{x}$)	SD	Remark
(N = 105)				
1	I use AI tools to prepare lesson plans for woodwork instruction.	2.55	0.60	LE
2	I integrate AI applications to simulate woodworking designs during lessons.	2.48	0.62	LE
3	I use AI to generate teaching aids such as diagrams, videos, or interactive materials.	2.60	0.58	LE
4	I use AI tools to assess students' practical and theoretical woodwork skills.	2.52	0.61	LE
5	I incorporate AI tools to provide personalized learning experiences for students.	2.50	0.59	LE
6	I use AI-powered plagiarism detection tools to check student assignments.	3.05	0.62	ME
7	I use AI to facilitate virtual simulations of woodworking processes for students.	3.10	0.63	ME
8	I use AI to track and analyze students' performance data.	2.58	0.57	LE
9	I employ AI platforms to enhance the efficiency of my teaching activities.	2.55	0.60	LE
10	I use AI tools to create interactive quizzes and assessments for students.	2.50	0.59	LE
11	I use AI to provide automated feedback to students on practical exercises.	2.48	0.61	LE
12	I use AI tools to organize and schedule instructional activities efficiently.	2.52	0.58	LE
13	I use AI to support collaborative learning among students through digital platforms.	2.50	0.60	LE
14	I integrate AI tools with other educational software to improve teaching and learning.	3.02	0.62	ME
15	I regularly update my instructional practices by adopting new AI tools available for teaching woodwork.	2.55	0.57	LE
Grand Mean/SD		2.63	0.60	Low Extent

Note: N = Number of Respondents; SD = Standard Deviation; SA = Strongly Agree; A = Agree

Table 2 shows the mean responses of the respondents on 15 items posed to determine the extent of adoption of AI as a tool for improving instructional delivery methods among wood technology teachers in higher institutions in North-central, Nigeria. The mean values of the respondents ranged

from 2.48 to 3.10, with a resulting grand mean of 2.63, which implies that the respondents collectively rated most of the items at a **low extent**, with only a few items at moderate extent, as indicators of their adoption of AI as a tool for improving instructional delivery methods among wood technology teachers. Also, the standard deviation of the items ranged from 0.57 to 0.63, with a resulting average standard deviation of 0.60, which indicates that the 15 items had standard deviations less than 1.96, showing that the respondents' ratings were not too far from the mean and were close to one another in their responses. This closeness of the responses adds value to the reliability of the mean.

Discussion of Findings

The findings of research question one revealed that the extent of awareness of AI as a tool for improving instructional delivery methods among wood technology teachers in higher institutions was high. This implies that wood technology teachers in the sampled higher institutions in North-central, Nigeria are generally knowledgeable about the potential applications of AI in teaching. Specifically, the respondents demonstrated awareness of AI tools in areas such as lesson planning, generation of teaching aids, creation of interactive assessments, tracking student performance, and facilitating personalized learning experiences. This high level of awareness suggests that teachers recognize the growing role of AI in enhancing the quality and efficiency of instructional delivery. It also indicates that, within the context of higher institutions in North-central, Nigeria, educators are increasingly exposed to technological innovations and are capable of leveraging AI to support practical and theoretical aspects of woodwork instruction.

The finding aligns with previous studies in educational technology and AI integration. For instance, Adeniyi and Ibrahim (2021) reported that lecturers in Nigerian universities demonstrated high awareness of digital and AI-driven tools in teaching and research, particularly in creating instructional materials and automating certain pedagogical processes. Similarly, Okonkwo and Ofoegbu (2022) found that lecturers across universities and colleges of education exhibited comparable levels of awareness regarding emerging AI technologies, suggesting that professional exposure to AI is becoming consistent across different types of higher institutions. Moreover, international studies, such as Al-Samarraie *et al.* (2021) indicate that lecturers worldwide are increasingly aware of AI tools in teaching, highlighting a global trend toward technological adoption in education. In the present study, the high awareness among wood technology teachers suggests readiness for the integration of AI into instructional practices, although actual adoption may depend on factors such as institutional support, availability of resources, and perceived usefulness of specific AI tools. The finding implies that wood technology teachers in higher institutions in North-central, Nigeria are sufficiently aware of AI tools, and that the primary challenges to their adoption now lie in factors other than awareness, such as access, training, or institutional support.

The findings of research question two revealed that the extent of adoption of AI as a tool for improving instructional delivery among wood technology teachers in higher institutions was low. This indicates that, despite the high level of awareness demonstrated by teachers, their actual use of AI tools in lesson planning, creation of teaching aids, interactive assessments, and performance tracking was limited. This low adoption may be attributed to several factors. First, access to AI-enabled platforms and necessary technological infrastructure in higher institutions may be inadequate, limiting teachers' ability to implement these tools effectively. Second, a lack of formal

training or professional development opportunities focused on the practical application of AI in teaching could hinder integration, even when teachers are aware of its potential benefits. Third, perceived complexity of AI tools or uncertainty about their effectiveness in improving learning outcomes may contribute to hesitation in adoption.

These findings are consistent with earlier studies. Adeniyi and Ibrahim (2021) noted that while lecturers were aware of digital and AI-driven instructional tools, actual utilization remained low due to challenges such as insufficient resources and lack of institutional support. Similarly, Okonkwo and Ofoegbu (2022) reported a gap between awareness and practical adoption of AI technologies among lecturers, highlighting the need for capacity building and infrastructure development. The low adoption observed in this study also resonates with international research. For example, Al-Samarraie *et al.* (2021) highlighted that, globally, awareness of AI in teaching is often higher than actual usage, with barriers including inadequate training, technological challenges, and resistance to change affecting adoption. This finding highlights the need for targeted interventions to promote the adoption of AI. Although teachers are aware of AI's potential to enhance instructional delivery, its practical application remains limited.

Conclusion

The study revealed that wood technology teachers in higher institutions in North-central, Nigeria possess a high level of awareness of AI as a tool for improving instructional delivery methods. Teachers demonstrated knowledge of AI applications in areas such as lesson planning, creation of teaching aids, interactive assessments, performance tracking, and personalized learning, indicating readiness to integrate AI into instructional practices. This finding suggested that awareness was no longer a major barrier to adoption, and that teachers were increasingly capable of leveraging AI to enhance the quality and efficiency of teaching in wood technology education.

Recommendations

The following recommendations were made based on the findings of the study:

1. Targeted training programmes and workshops should be organized to equip wood technology teachers with practical skills for effectively integrating AI into lesson planning, teaching aids, assessments, and performance tracking.
2. Higher institutions should provide adequate technological resources, such as AI-enabled software, computers, and stable internet access, alongside institutional policies and support that encourage and guide teachers in implementing AI tools in their teaching practices.

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HUMAN–AI SYNERGY: BUILDING AN INNOVATIVE WORKFORCE FOR NATIONAL SECURITY IN THE AGE OF ARTIFICIAL INTELLIGENCE

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Abstract

Artificial intelligence (AI) is rapidly reshaping the national security landscape, offering unprecedented capabilities in threat detection, cyber defense, autonomous systems, and crisis management. Yet, the effectiveness of these technologies depends not only on their sophistication but also on the preparedness of the workforce that deploys them. This paper explores the critical intersection of AI integration and workforce innovation in ensuring national security. It argues that while AI enhances operational efficiency and decision-making, human expertise remains indispensable for ethical oversight, strategic judgment, and adaptive leadership. The discussion is structured around three pillars. First, the role of AI in security operations, highlighting applications in predictive analytics, cybersecurity, and autonomous platforms. Second, workforce transformation, emphasizing upskilling, human–machine teaming, and the importance of diversity in building resilient institutions. Third, governance and ethics, addressing accountability, privacy, and international policy frameworks. Looking forward, the paper considers emerging technologies such as quantum computing and generative AI, as well as the role of public–private partnerships in advancing secure and responsible innovation. The paper proposes a framework for human–AI synergy that integrates technological advancement with workforce readiness and ethical governance. It concludes that national security in the AI era will rely not only on technological superiority but equally on cultivating a skilled, adaptive, and ethically grounded workforce capable of leveraging AI responsibly and innovatively.

Keywords: Artificial Intelligence; National Security; Governance; Workforce;

Introduction

Artificial intelligence (AI) has become a transformative force in modern national security, providing tools that enable faster decision-making, enhanced threat detection, and more effective responses to emerging challenges. Globally, security institutions are integrating AI into predictive analytics, surveillance, cyber defense, and crisis management. In contexts like Nigeria, where terrorism, insurgency, kidnapping, and banditry remain pressing threats across the North-East, North-West, North-Central, and even parts of the South, AI presents opportunities to overcome traditional intelligence and response gaps.

Groups such as Boko Haram and its splinter factions (e.g., ISWAP) have exploited porous borders, rugged terrain, and weak intelligence systems to sustain operations in the North-East. Similarly, bandit groups in the North-West and North-Central have weaponized mobility and local knowledge to evade conventional security responses, while kidnapping-for-ransom has spread from rural corridors to urban centers, creating widespread insecurity and eroding trust in state institutions (UNIDIR, 2024; Global Initiative, 2024). Traditional security strategies, often manpower-intensive and reactive, have struggled to keep pace with these decentralized and rapidly evolving threats.

Here, AI offers significant advantages. Predictive modeling can anticipate attacks based on historical patterns; geospatial AI tools can map insurgent movement across difficult terrains; and

natural language processing can sift through intercepted communications to extract actionable intelligence. However, technology alone cannot guarantee security. Effective use of AI requires a skilled, adaptive, and ethical human workforce capable of interpreting outputs, applying insights, and making judgment calls under pressure (NITDA, 2024; NDC, 2025). Without such human oversight, the risk of misuse, error, or erosion of public trust increases.

Thus, Nigeria's national security faces a dual challenge: integrating advanced AI technologies into operational contexts while simultaneously innovating its workforce through reskilling, training, and leadership development. Addressing both pillars together, technology and workforce are essential to building a resilient, responsive, and accountable security architecture capable of countering Boko Haram, insurgency, kidnapping, and banditry across all regions of the country. The persistent threats such as Boko Haram in the North-East, banditry and kidnapping in the North-West and Middle Belt, and kidnappings in train corridors and highways, present complex security challenges. Traditional intelligence, human patrols, and reactive responses have had limited success. AI and related technologies present promising tools to augment detection, analysis, and response capacities.

One of the key areas where AI could make a difference is predictive policing. Researchers have argued for applying predictive policing in Nigeria to anticipate crime hotspots and allocate security resources more effectively. For example, Eke (2025) explores "Artificial Intelligence-Based Predictive Policing" in Nigeria, detailing how machine learning models can use historical crime data, geographic patterns, socio-demographic indicators, and past violence events to forecast where bandit attacks or kidnappings are more likely. Such forecasting, if done responsibly and with oversight, could help security agencies pre-position patrols or rapid-response units in high-risk zones.

Another relevant capability is geospatial intelligence. Studies of Boko Haram's insurgency show that mapping terrain, forest vegetation, settlement patterns (villages vs. displaced camps), and routes into and out of areas like the Sambisa Forest or Lake Chad Basin can help security forces predict likely infiltration or ambush points. For example, Nte, Abdulaziz & Uzorka (2020) were of the view that geospatial intelligence is "potent" for counter-terrorism strategy in Nigeria, though they also pointed out gaps in data accuracy and timeliness. Emergency and crisis response can also be enhanced via AI-driven systems. Applications like "Alerte" use real-time location sharing, AI-driven safety recommendations, and coordination mechanisms to speed up emergency responses when kidnappings or attacks occur. Such tools are helpful, especially in remote or underserved regions, where delays in response lead to higher casualties or loss of life.

Political leaders in Nigeria are increasingly recognizing the importance of "early threat detection and coordinated response" powered by technology. The Governors' Forum recently backed the deployment of technological innovations by the military for threat detection and coordinated responses, signaling institutional readiness to integrate technological tools in insecure hotspots. (The Nation's Newspaper paper 2025). Additionally, the Centre for Crisis Communication has explicitly called on the military to "exploit the capacity of AI to help analyze vast amounts of data, identify patterns of criminal activity, and predict threats before they occur," especially in the contexts of terrorism and insurgency. Despite these calls however, there are constraints. Challenges include lack of reliable, timely data; infrastructural limitations (e.g. stable power,

internet connectivity in rural areas); capacity for handling AI tools; ethical issues related to privacy and profiling; and the risk that predictions could lead to overreach or false positives

This paper explores how AI is being integrated into national security, the skills and transformations required of the workforce, the ethical and governance issues involved, and the opportunities that lie ahead. It proposes a framework for **human–AI synergy** that balances technological capability, workforce innovation, and accountability, ensuring that AI strengthens security while upholding democratic values.

Transforming the Workforce for the AI Era

Technology alone cannot guarantee security; in Nigeria’s case the human factor remains decisive. Decades of insurgency in the North-East (Boko Haram/ISWAP), the rise of banditry and kidnapping in the North-West and Middle Belt, and proliferating criminal networks across highways and urban corridors have shown that tactical and strategic advantages are as much about people and institutions as about equipment. To make AI effective against these threats, security actors need new skills: data literacy, geospatial analysis, digital forensics, cybersecurity, and the ability to supervise and interpret algorithmic outputs in operational settings (NDC, 2025; DSA / Nigerian Air Force, 2025). Recent Nigerian defence and security training initiatives such as AI and cyber courses at the National Defence College (NDC), AI training launched by the Nigerian Air Force Research & Development Institute, and expanded digital/cyber training for police officers demonstrate institutional moves to equip personnel with these competencies (NDC, 2025; Nigerian Air Force, 2025; Nigeria Police Force, 2025).

Reskilling and upskilling must be tailored to the local problem set. For example, analysts supporting counter-insurgency in the Sambisa/Lake Chad theatre must combine traditional HUMINT (human intelligence) with geospatial analytics and satellite imagery interpretation so that patterns of movement, supply lines, and likely ambush corridors are detected early. Likewise, units combating kidnapping and banditry in the North-West benefit from rapid information-sharing platforms, mobile forensics, and AI-enabled hotspot forecasting capabilities that require both technical training and doctrinal changes on how intelligence is produced and acted upon (UNIDIR, 2024). Training should therefore blend classroom instruction, hands-on cyber/forensics labs, and field exercises that simulate AI-augmented operations, so that officers learn not only tools but also how to incorporate AI outputs into ethical, legally-sound decisions. Recent hands-on cyber and digital forensics courses at Nigerian training institutions are a step in this direction (NDC, 2025).

Human–AI collaboration also demands new leadership and organizational culture. Commanders and police executives must understand AI’s limits, model human-in-the-loop oversight, and promote interdisciplinary teams that pair data scientists with experienced field operatives. Rehabilitation and reintegration programs for former Boko Haram combatants further illustrate the need for psychosocial, vocational and community-based capacities that go beyond kinetic responses; integrating data systems to track reintegration outcomes and risk indicators would require case-workers and security officials to be trained in data ethics and monitoring approaches (UNODC; VOA, 2023). Without such cross-cutting capabilities, AI systems risk producing alerts that cannot be operationalized or, worse, generate biased profiling that harms communities and undermines trust. Moreover, inconsistent data collection across states, limited broadband and power in rural conflict zones, shortages of qualified trainers, and budgetary constraints. Civil

society and international partners are already contributing to capacity building and community resilience programmes targeted investments in teacher training, community policing, and early-warning systems to help reduce recruitment pools for violent groups and create better data for predictive systems (Global Initiative, 2024; UNICEF, 2024). Importantly, training programs must embed ethics, privacy, and community engagement modules so that AI deployment does not aggravate grievances or erode civil liberties.

Ethics, Governance, and Accountability

The integration of AI into national security brings undeniable opportunities, but it also raises profound ethical, legal, and governance challenges. In Nigeria, where terrorism, insurgency, kidnapping, and banditry remain pressing threats, the deployment of AI in surveillance, cyber operations, and autonomous defense systems must be balanced with democratic accountability, human rights, and the rule of law. Without appropriate checks, technologies designed to protect citizens may inadvertently infringe upon their freedoms or even exacerbate insecurity.

One of the most critical ethical issues is privacy. AI-driven surveillance systems, facial recognition tools, and digital monitoring platforms could help track Boko Haram cells, identify kidnappers' hideouts, or monitor suspicious financial flows. However, Nigeria lacks robust data protection enforcement, making the risk of misuse significant. Scholars warn that unregulated surveillance can erode public trust, expose citizens to abuse, and fuel grievances that violent groups exploit for recruitment (ResearchGate, 2024). A key example is the controversy over SIM card registration and surveillance measures, which, while aimed at countering kidnappers and insurgents, raised concerns about data privacy and oversight (UNODC, 2022).

Accountability is another challenge. Security institutions must remain subject to democratic oversight even when operating in high-threat environments. International observers emphasize that AI in counter-terrorism must include "human-in-the-loop" safeguards to prevent arbitrary or automated decisions, such as wrongful arrests or misclassification of innocent individuals as insurgents (UNIDIR, 2024). In Nigeria, where weak institutional oversight has often undermined security reforms, ensuring transparent governance structures around AI adoption is critical.

At the policy level, Nigeria has begun exploring AI governance through initiatives like the National Artificial Intelligence Strategy, which calls for ethical frameworks, sector-specific guidelines, and public engagement in AI adoption (NITDA, 2023). Still, governance must be tailored to security realities by establishing clear standards for how AI is procured, how data is stored, who can access it, and under what legal authority. Embedding human rights protections into military doctrine, police training, and intelligence practices is essential to prevent overreach.

Globally, Nigeria can benefit from emerging international norms. The UN and African Union are advancing discussions on the responsible use of AI in defense and security, emphasizing transparency, proportionality, and civilian protection (AU, 2022; UNIDIR, 2024). As a frontline state facing both terrorism and transnational organized crime, Nigeria's participation in these dialogues is vital for harmonizing national policies with international standards.

Ultimately, ethics and governance in AI deployment for national security must rest on three pillars: legal safeguards, institutional accountability, and community trust. Without these, even the most

advanced AI systems risk being counterproductive, fueling mistrust, enabling abuse, and undermining the very security they are designed to provide

Future Outlook: Next-Generation Challenges and Opportunities

As artificial intelligence continues to evolve, Nigeria's national security landscape will face both new risks and novel opportunities. Emerging technologies such as quantum computing, generative AI, and advanced autonomous systems promise to reshape how threats are detected, analyzed, and countered. At the same time, adversaries including terrorist organizations like Boko Haram and criminal networks involved in kidnapping and banditry are increasingly exploring digital tools to enhance recruitment, disinformation, and operational coordination (UNODC, 2022; ResearchGate, 2024).

Generative AI presents a double-edged sword. On the one hand, it can be used to produce deepfake videos, propaganda, or fraudulent communications, potentially amplifying Boko Haram's ideological messaging or kidnappers' ransom schemes. The Centre for Strategic and International Studies (CSIS, 2023) warn that extremist groups worldwide are experimenting with generative AI to create persuasive content at low cost. For Nigeria, this risk is significant given the role of online radicalization in sustaining insurgency in the North-East. On the other hand, generative AI can also be harnessed defensively for instance, to simulate conflict scenarios for training, generate synthetic data for predictive policing models, and assist in producing multilingual communication campaigns to counter violent extremism (UNDP, 2023).

Quantum computing, though still at an early stage, could disrupt Nigeria's cybersecurity landscape. Bandit groups and insurgents often exploit weak digital systems for financial fraud, ransom transfers, and illicit trade. In the future, quantum-enabled adversaries could break traditional encryption, undermining government and military communications. Conversely, if Nigeria invests early in quantum-resistant encryption and partners with international research bodies, quantum technology may become an asset in securing communications and processing vast intelligence datasets with unprecedented speed (NITDA, 2023).

Public-private partnerships (PPPs) will be central to Nigeria's preparedness. Most of the technical expertise, infrastructure, and innovation capacity in AI lies within the private sector, including fintech, telecom, and cybersecurity firms. Recent collaborations, such as the adoption of AI-driven emergency response applications and private cybersecurity training initiatives, highlight the value of PPPs in addressing insecurity (The Guardian, 2025). Institutionalizing such partnerships could help the military and police access cutting-edge tools while enabling private actors to contribute to national stability. As the African Union has noted, a collaborative ecosystem involving states, academia, and private industry will be crucial to the ethical and effective use of AI in security (AU, 2022).

Finally, continuous adaptation must be built into Nigeria's security architecture. The rapidly changing nature of AI means doctrines, training, and regulations must be iterative rather than static. Agencies combating Boko Haram or banditry cannot rely solely on legacy approaches, instead they must embed foresight capabilities, scenario planning, and adaptive leadership into their operations (UNIDIR, 2024). Preparing for next-generation challenges is not simply about

acquiring advanced technologies but about fostering resilience, accountability, and innovation within Nigeria's institutions.

A Framework for Human–AI Synergy in Nigeria's National Security

To translate AI's potential into safer communities across Nigeria from the Lake Chad and Sambisa theatres to the bandit-affected Middle Belt and North-West a practical, implementable framework is needed. Building on the paper's earlier analysis, this framework rests on three interconnected pillars: Technology, Workforce, and Governance. Each pillar targets specific problems posed by Boko Haram, insurgency, kidnapping and banditry, and together they aim to ensure that AI deployments are effective, ethical, and sustain public trust.

Technology pillar: fit-for-purpose AI tools and data integration. Technology must be chosen and configured to the operational realities on the ground. In Nigeria, this means AI systems that can fuse sparse local data (police reports, community tips, and satellite imagery) into actionable geospatial intelligence to identify likely ambush corridors, routes used by kidnappers, and evolving hotspot clusters (UNIDIR, 2024). Practical tools include AI-assisted geospatial analytics for the Sambisa/Lake Chad regions, anomaly detection models for early warning of massed movements, and lightweight mobile reporting platforms (e.g., emergency apps) that feed local signals into centralized fusion centers (The Guardian, 2025). These systems must be interoperable with existing Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) architectures, and designed for low-bandwidth, intermittent connectivity typical of many conflict zones. The National AI Strategy provides direction on prioritizing such sectoral AI solutions for public safety and resilience. (NITDA, 2024; Guardian, 2025).

Workforce pillar skills, doctrine, and human-in-the-loop practices. Even the best systems fail without trained people. Nigerian security actors need multi-disciplinary teams combining data scientists, geospatial analysts, digital forensics experts and experienced field operatives. Training initiatives (e.g., cyber and AI courses at the National Defence College and the Nigerian Air Force's AFRDI AI training) show institutional momentum for building these skills (NDC, 2025; Defence Space Administration / NAF, 2025). Capacity building should emphasize: (1) data literacy and model interpretation so that analysts can interrogate AI outputs; (2) human-in-the-loop decision protocols to avoid automated overreach; and (3) operational field drills that integrate AI alerts into patrol routing, rapid-response dispatch and community liaison critical for effective responses to bandit attacks or kidnapping incidents. Equally important are cross-training and career pathways so analysts remain embedded with operational units rather than siloed in remote data centers. (NDC, 2025; DSA/NAF, 2025).

Governance pillar law, oversight, and community trust. Strong governance protects civilians and sustains legitimacy. In Nigeria this requires clear legal frameworks for data collection/use (consistent with the National AI Strategy), transparent procurement rules for security technologies, and independent oversight mechanisms to review surveillance and profiling practices. UNIDIR's community-level work on banditry underscores how lack of accountable institutions erodes trust and hampers reporting an outcome that would blunt AI systems dependent on community signals (UNIDIR, 2024). Governance must also mandate privacy protections, auditability of models, redress mechanisms for wrongful targeting,

and ethical guidelines for any autonomous or semi-autonomous systems used in operations. International and regional norms (AU, UN) should guide national policy so that counter-terrorism and counter-criminality measures do not inadvertently violate human rights,

Integration: how the pillars work together. Operational success demands tight integration. For example, an AI model (Technology) that flags an emergent kidnapping pattern should trigger a response protocol that routes an alert to a trained analyst embedded in a regional command (Workforce), who evaluates the model's confidence and legal basis before authorizing deployment of response teams all under a transparent oversight trail (Governance). Capacity building must therefore include training on legal/ethical constraints and on how to route, validate and act on AI outputs. Pilot projects such as AI-assisted emergency response apps and SOC drills run by defence space and cyber units provide blueprints for staged rollout and iterative improvement (Guardian, 2025; NDC, 2025; DSA/NAF, 2025).

Implementation priorities and risks. Short-term priorities include: (1) establishing interoperable data-fusion hubs in high-risk states (with privacy protections); (2) expanding practical AI and cyber courses for security personnel; (3) running joint public–private pilots with telecoms and civil society to improve data flows and trust; and (4) embedding independent auditing and community oversight in pilot contracts. Key risks are biased models from poor or uneven data, over-reliance on automated targeting, power/connectivity constraints in rural zones, and procurement that outpaces governance capacity. The UNIDIR and Global Initiative findings on banditry and community impacts reinforce that technological fix must be paired with social and institutional investments to avoid worsening grievances (UNIDIR, 2024; Global Initiative, 2024).

Conclusion

National security in the AI era requires more than advanced machines; it demands people who can apply, supervise, and innovate with these tools in complex, dynamic environments. For Nigeria, where threats such as Boko Haram insurgency, kidnapping, and banditry continue to undermine safety and development, artificial intelligence offers opportunities to transform surveillance, intelligence analysis, and rapid response. Yet, the true measure of success lies in the ability of trained personnel to integrate AI insights into strategy, operations, and community engagement in ways that are both effective and accountable.

This paper has argued that sustainable security outcomes depend on human–AI **synergy** built on three interconnected pillars: technology tailored to Nigeria's realities, a **workforce** empowered with new skills and adaptive leadership, and governance frameworks that ensure ethical deployment and public trust. Bridging these pillars calls for deliberate investment in technical infrastructure, reskilling initiatives across security agencies, transparent legal frameworks, and meaningful public–private–community partnerships.

Policymakers must prioritize supportive policy environments that encourage responsible AI adoption; educators must design training curricula that equip security personnel with practical and ethical competencies; and practitioners must embrace AI tools while preserving human judgment and accountability. The path forward is not simply about catching up with global AI trends but about leveraging technology to meet Nigeria's specific security challenges with innovation,

resilience, and inclusivity. Ultimately, embracing human–AI synergy is not optional it is a national imperative for securing Nigeria’s future against evolving threats while safeguarding the values of justice, trust, and human dignity.

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BARRIERS AND ENABLERS OF ARTIFICIAL INTELLIGENCE ADOPTION FOR EFFECTIVE TEACHING AMONG TEACHERS IN VOCATIONAL ENTERPRISES INSTITUTES IN ABUJA, NIGERIA

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Abstract

The study examined the barriers and enablers of Artificial Intelligence (AI) adoption for effective teaching among teachers in Vocational Enterprises Institutes (VEIs) in Abuja, Nigeria. The study was guided by two research questions and two null hypotheses. A cross-sectional descriptive survey design was employed, which enabled the collection of data at a single point in time. The population of the study consisted of all 210 trade teachers across the six VEIs in Abuja, and a census approach was used to ensure comprehensive coverage. Data were collected using a structured questionnaire designed on a five-point Likert scale. The instrument was validated by three experts and its reliability was confirmed through a pilot test, which yielded overall Cronbach's alpha coefficients of 0.89. Data analysis involved mean and standard deviation to answer the research questions and independent samples z-test to test the null hypotheses at the 0.05 level of significance. Findings revealed that inadequate training, poor internet connectivity, limited ICT facilities, and resistance to change were barriers to AI adoption, while regular training, ICT resources, administrative support, government funding, peer collaboration, and reliable internet access were identified as key enablers. The findings further indicated no significant differences between highly experienced and moderately experienced teachers in their perceptions of both barriers and enablers. It was recommended that the Federal Capital Territory Administration through the Department of Mass Education provide targeted professional development, improve ICT facilities and internet infrastructure, institutionalize regular training workshops, strengthen administrative support, and sustain government funding to promote effective AI adoption in VEIs.

Keywords: Artificial Intelligence, Barriers, Enablers, Effective Teaching, Vocational Enterprises Institutes, Abuja

Introduction

Artificial Intelligence (AI) has rapidly become a driving force in transforming how education is delivered, enhancing efficiency, personalization, and learner engagement in many parts of the world. In Nigeria efforts are underway to integrate AI into formal educational settings for improved learning outcomes of students, including that of Vocational Enterprises Institutes (VEIs) (Manir, 2025). VEIs are specifically well-positioned to benefit from AI because of their mandate to impart practical skills and prepare students for changing technological demands. However, these institutions still face considerable challenges, including insufficient infrastructure, limited digital literacy among teachers, and weak policy support that hamper full utilization of AI tools in teaching (Osagie, 2025; Ajayi *et al.*, 2019). These challenges threaten the potential of AI to foster effective teaching in VEIs.

Effective teaching through AI depends not only on the availability of technology but also on supportive institutional and pedagogical enablers. Barriers such as inadequate training, poor internet connectivity, limited ICT facilities, and resistance to change can significantly inhibit teachers from adopting AI. Studies in Nigeria have documented these hindering factors: for example, the study on digital literacy and adoption of AI among Social Studies teachers in Edo State reported infrastructural, policy, and personal barriers impeding AI adoption (Osagie, 2025). Meanwhile, research on AI integration into Nigerian educational systems highlighted technological, administrative, and socio-economic challenges as key constraints (Eke, 2024). Thus, while teachers may recognize the benefits of AI tools, the presence of such barriers limits translation into practice, making it crucial to identify enabling factors that can offset these impediments.

Identifying enablers is therefore central if VEIs in Abuja are to move beyond mere interest in AI adoption to actual implementation that enhances teaching effectiveness. Enablers may include regular training, strong administrative support, sufficient ICT resources, reliable internet access, peer collaboration, and appropriate policy incentives factors which have been found in literature elsewhere to facilitate technology adoption (Ajayi & Olusanya, 2025; Eke, 2024). Without these enablers, barriers remain entrenched, and potential benefits of AI in education remain unrealized, especially in VEIs where practical, skills-based teaching must keep pace with technological changes.

The persistence of both barriers and enablers across contexts suggests that experience alone (e.g., years of teaching) does not guarantee either successful AI adoption or awareness of what supports are necessary. In several Nigerian studies, teaching experience did not significantly differentiate perceptions of barriers or supports (Eke, 2024; Scherer *et al.*, 2023). Because VEI teachers in Abuja share many systemic constraints, it is important to investigate whether highly experienced and moderately experienced teachers differ in how they perceive barriers and enablers of AI adoption for effective teaching. Addressing this problem is essential for designing interventions that are both inclusive and targeted, ensuring that all teachers, not just those with more experience are supported to adopt AI tools and improve teaching quality in VEIs in Abuja.

Statement of the Problem

Ideally, teachers in VEIs in Nigeria are expected to leverage emerging technologies such as AI to enhance teaching effectiveness, foster learner-centered instruction, and align vocational training with industry 4.0 demands. In reality, however, adoption remains low. Evidence shows that teachers face challenges including inadequate ICT infrastructure, insufficient digital literacy, weak policy support, and limited training opportunities (Ajayi *et al.*, 2019; Osagie, 2025). These factors hinder integration of AI tools, leaving instruction largely traditional and disconnected from technological innovations. Although teachers in other contexts benefit from professional experience (Scherer *et al.*, 2023), studies in Nigeria indicate that both highly and moderately experienced teachers encounter similar systemic barriers (Eke, 2024).

Low adoption is largely due to insufficient investment in infrastructure, capacity building, and policy implementation. While reforms in Nigeria's vocational education sector have emphasized ICT and innovation, resource provision and teacher support have been inadequate (NBTE, 2024; Ifinedo, 2020). Some interventions, such as digital literacy workshops, have been introduced but

not sustained or scaled to address persistent gaps (Murithi & Yoo, 2021; Ajayi & Olusanya, 2025). As a result, weak adoption continues despite recognition of AI's potential to transform teaching and learning.

The persistence of these challenges has serious consequences. Without adequate adoption, VEIs cannot fully achieve their mandate of producing industry-ready graduates with 21st-century skills, undermining institutional performance and national development goals such as reducing unemployment and advancing technology (Manir, 2025). If unaddressed, AI integration risks becoming another unfulfilled policy aspiration with wasted investments and declining stakeholder confidence. This study therefore examines barriers and enablers of AI adoption for effective teaching among VEI teachers in Abuja, Nigeria, providing evidence to guide policymakers, administrators, and educators in strengthening vocational education through technology integration.

Aim and Objectives of the Study

The aim of the study was to examine the barriers and enablers of AI adoption for effective teaching among teachers in VEIs in Abuja, Nigeria. Specifically, the objectives of the study are:

1. To identify the barriers hindering the adoption of AI for effective teaching among teachers in VEIs in Abuja, Nigeria.
2. To determine the enablers that facilitate AI adoption for effective teaching among teachers in VEIs in Abuja, Nigeria.

Research Questions

The following research questions were raised and answered:

1. What barriers hinder the adoption of AI for effective teaching among teachers in VEIs in Abuja, Nigeria?
2. What enablers facilitate the adoption of AI for effective teaching among teachers in VEIs in Abuja, Nigeria?

Hypotheses

The following null hypotheses were formulated and tested at 0.05 level of significance:

H_{0 1} : There is no significant difference in the mean responses of highly experienced and moderately experienced teachers regarding the barriers hindering AI adoption for effective teaching in VEIs in Abuja, Nigeria.

H_{0 2} : There is no significant difference in the mean responses of highly experienced and moderately experienced teachers regarding the enablers facilitating AI adoption for effective teaching in VEIs in Abuja, Nigeria.

Methodology

This study adopted a cross-sectional descriptive survey design. A descriptive survey is appropriate for collecting data on the attitudes, opinions, and practices of a defined population and describing them as they exist without experimental manipulation of variables (Creswell & Creswell, 2021). The study was carried out in Abuja, Nigeria. The target population consisted of all 210 trade

teachers in VEIs in the study area. Given the manageable size of the population, a census approach was adopted. The instrument for data collection was a structured questionnaire developed by the researcher. The instrument consisted of three sections: Section A gathered demographic information; Section B contained six items addressing Research Question One; and Section C contained six items addressing Research Question Two. Responses to the items were rated on a five-point Likert scale adapted for agreement as follows: Strongly Agree (5), Agree (4), Undecided (3), Disagree (2), and Strongly Disagree (1).

The validity of the instrument was established through face and content validation by three experts: one in Educational Technology and two in Technical and Vocational Education, who examined the instrument for clarity, relevance, and alignment with the study objectives. To ensure reliability, a pilot study was conducted outside the study area using 20% of the population. The Cronbach's alpha coefficients obtained were 0.84 for the barriers scale, 0.87 for the enablers scale, and 0.89 overall, indicating acceptable internal consistency (Edwards *et al.*, 2021). The instrument was administered both physically and electronically to maximize coverage and convenience. Printed copies were distributed, while soft copies were sent via email and WhatsApp platforms to teachers who were unavailable in person. Completed instruments were collected within a four-week period. Data were analysed using mean and standard deviation to answer the research questions and independent samples z-test to test the null hypotheses at the 0.05 level of significance.

Results

Research Question 1

What barriers hinder the adoption of AI for effective teaching among teachers in VEIs in Abuja, Nigeria? Results for answering research question one are presented in Table 1.

Table 1: Average mean and standard deviation for the responses of the respondents on barriers hinder the adoption of AI for effective teaching among teachers in VEIs in Abuja, Nigeria

S/N	Items	Mean	SD	Decision
1	Lack of adequate training limits my ability to adopt AI in teaching.	4.42	1.12	Agreed
2	Limited access to ICT facilities hinders AI adoption in my teaching.	4.38	1.15	Agreed
3	High cost of AI-related tools discourages my adoption of AI.	4.44	1.08	Agreed
4	Poor internet connectivity affects my ability to use AI effectively.	4.55	1.20	Agreed
5	Insufficient technical support discourages me from using AI in teaching.	4.47	1.09	Agreed
6	Negative attitudes and resistance to change limit AI adoption.	4.40	1.10	Agreed
	Grand Mean	4.44	1.12	Agreed

Table 1 shows mean scores ranging from 4.38 to 4.55 and a grand mean of 4.44. This indicates that respondents agreed on the six barriers hindering AI adoption for effective teaching in VEIs in Abuja, Nigeria.

Research Question 2

What enablers facilitate the adoption of AI for effective teaching among teachers in VEIs in Abuja, Nigeria? Results for answering research question two are presented in Table 2.

Table 2: Average mean and standard deviation for the responses of the respondents on enablers facilitate the adoption of AI for effective teaching among teachers in VEIs in Abuja, Nigeria

S/N	Items	Mean	SD	Decision
1	Regular training programs would enhance my ability to adopt AI in teaching.	4.18	0.92	Agreed
2	Provision of adequate ICT facilities would improve AI adoption in teaching.	4.12	0.95	Agreed
3	Government support and funding would encourage teachers to adopt AI.	4.05	0.98	Agreed
4	Administrative support motivates me to integrate AI into my teaching practices.	4.20	0.87	Agreed
5	Peer collaboration and knowledge sharing encourage AI adoption.	4.15	0.90	Agreed
6	Availability of reliable internet connectivity would enable effective AI use.	4.10	0.94	Agreed
Grand Mean		4.13	0.93	Agreed

Table 2 shows mean scores ranging from 4.05 to 4.20 and a grand mean of 4.13. This indicates that respondents agreed on the six enablers facilitating AI adoption for effective teaching in VEIs in Abuja, Nigeria.

Hypothesis One

There is no significant difference between the mean responses of highly experienced and moderately experienced teachers regarding the barriers hindering AI adoption for effective teaching in VEIs in Abuja, Nigeria. Results for testing hypothesis one are contained in Table 3.

Table 3: Independent z-test for testing the significant difference between the mean responses of highly experienced and moderately experienced teachers regarding the barriers hindering AI adoption for effective teaching in VEIs in Abuja, Nigeria.

Groups	N	Mean	SD	df	z	Sig.
Highly Experienced	85	2.50	1.11	208	1.325	.192
Moderately Experienced	125	2.38	1.13			

The p-value (.192) presented in Table 3 is greater than 0.05, indicating no significant difference between the mean responses of highly experienced and moderately experienced teachers regarding the barriers hindering AI adoption. Hence, hypothesis one was accepted.

Hypothesis Two

There is no significant difference between the mean responses of highly experienced and moderately experienced teachers regarding the enablers facilitating AI adoption for effective teaching in VEIs in Abuja, Nigeria. Results for testing hypothesis two are contained in Table 4.

Table 4: Independent z-test for testing the significant difference between the mean responses of highly experienced and moderately experienced teachers regarding the enablers facilitating AI adoption for effective teaching in VEIs in Abuja, Nigeria

Groups	N	Mean	SD	df	z	Sig.
Highly Experienced	85	4.18	0.91	208	1.210	.232
Moderately Experienced	125	4.08	0.95			

The p-value (.232) shown in Table 4 is greater than 0.05, indicating no significant difference between the mean responses of highly experienced and moderately experienced teachers regarding the enablers facilitating AI adoption. Hence, hypothesis two was accepted.

Findings

1. Inadequate training, poor internet connectivity, limited ICT facilities, and resistance to change were found to be barriers hindering the adoption of AI among teachers for effective teaching in VEIs in Abuja, Nigeria.
2. There was no significant difference in the mean responses of highly experienced and moderately experienced teachers regarding the barriers hindering AI adoption for effective teaching in VEIs in Abuja, Nigeria.
3. Regular training, ICT resources, administrative support, government funding, peer collaboration, and reliable internet access were found to be enablers facilitating AI adoption among teachers for effective teaching in VEIs in Abuja, Nigeria.
4. There was no significant difference in the mean responses of highly experienced and moderately experienced teachers regarding the enablers facilitating AI adoption for effective teaching in VEIs in Abuja, Nigeria.

Discussion of Findings

Findings on barriers hindering AI adoption among teachers in Abuja's VEIs revealed inadequate training, poor internet connectivity, limited ICT facilities, and resistance to change as major challenges. This indicates that while AI integration is globally promoted, systemic and infrastructural issues in Abuja restrict adoption. The finding supports Ajayi *et al.* (2019), who reported insufficient training and unreliable infrastructure in Nigeria, and Ejiofor and Uche (2023), who found similar obstacles among African teachers. However, it contrasts with Ning *et al.* (2025), who reported that structured training and adequate ICT encouraged adoption. The difference may stem from Abuja's persistent resource and support gaps. The implication is that AI adoption will remain weak unless infrastructure, training, and institutional support are deliberately strengthened.

Regarding the hypothesis on barriers between highly and moderately experienced teachers, no significant difference was found, showing that both categories faced similar constraints. This is consistent with Viberg *et al.* (2023) and Graham *et al.* (2020), who noted that systemic barriers outweigh teacher experience. It differs from Scherer *et al.* (2023), who found experienced teachers more able to navigate technology integration. In Abuja, uniform institutional shortcomings explain the similarity. The implication is that interventions should target systemic challenges for all teachers, not by experience level.

Findings on enablers revealed that regular training, ICT resources, administrative support, government funding, peer collaboration, and reliable internet were key factors supporting adoption. This suggests that teachers view external supports as essential for AI integration. The finding agrees with Murithi and Yoo (2021), who emphasized infrastructure, and Akinrinola *et al.* (2020), who highlighted support and collaboration. By contrast, Scherer *et al.* (2023) stressed individual confidence in developed contexts. In Abuja, systemic supports remain decisive, meaning adoption depends on continuous investment in resources, training, and policy frameworks.

On the hypothesis concerning enablers between highly and moderately experienced teachers, no significant difference was found, indicating both groups valued similar supports. This aligns with Gore *et al.* (2024) and Viberg *et al.* (2023), who argued that external supports, not experience, drive adoption. However, it contrasts with Ning *et al.* (2025), who found experienced teachers more confident when training was available. The similarity in Abuja reflects shared dependence on institutional resources and policies. The implication is that strategies should be designed to strengthen systemic supports across the board rather than tailored by experience level.

Conclusion

The study examined barriers and enablers of AI adoption for effective teaching in VEIs in Abuja, Nigeria. Findings revealed inadequate training, poor internet connectivity, limited ICT facilities, and resistance to change as major barriers. No significant difference was found between highly and moderately experienced teachers, indicating that these challenges are systemic. Conversely, regular training, ICT resources, administrative support, government funding, peer collaboration, and reliable internet were identified as key enablers, with no significant difference between teacher groups, showing that supportive structures benefit all teachers equally. In conclusion, while systemic barriers persist, strengthening these enablers can enhance AI adoption in VEIs, calling for holistic interventions that address constraints and reinforce support for teachers.

Recommendations

Based on the findings of the study, the following recommendations are made:

3. The Federal Capital Territory Administration through the Department of Mass Education should provide targeted professional development programs for all VEI teachers, expand ICT facilities, and improve internet infrastructure to reduce resistance to change and build teachers' confidence in adopting AI for effective teaching.
4. The Federal Capital Territory Administration should institutionalize regular training workshops, ensure consistent government funding, encourage peer collaboration, and provide sustained administrative support so that teachers in VEIs have the necessary resources and enabling environment to effectively integrate AI into teaching and learning.

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INDUSTRIAL AND TECHNOLOGY EDUCATION LECTURERS' PERCEIVED USEFULNESS AND BARRIERS TO ADOPTION OF ARTIFICIAL INTELLIGENCE TOOLS FOR RESEARCH IN HIGHER INSTITUTIONS IN NORTH-CENTRAL, NIGERIA

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Abstract

The study investigated the perceived usefulness and barriers to adoption of AI tools for research purposes among ITE lecturers in higher institutions in North-central Nigeria. Three research questions and three null hypotheses guided the study. A descriptive survey design was used for the study. The targeted population of the study was 111 respondents comprising of 54 ITE University lecturers and 57 ITE colleges of education lecturers in North-Central Nigeria. A 45 items structured questionnaire validated by three experts was used for data collection. The instrument was pilot tested in Kaduna Polytechnic using 10 ITE lecturers. Using Cronbach's Alpha statistical technique, the overall reliability coefficient of the instrument was found to be 0.82. Data collected were coded and analyzed using the Statistical Package for Social Sciences (SPSS, Version 26). The findings of the study revealed that the extent of ITE lecturers' awareness of AI tools for research purposes was at a very high extent with a grand mean ($\bar{X} = 4.40$). The study also revealed that the perceived usefulness of AI tools for research purposes among ITE lecturers in higher institutions was very high with a grand mean ($\bar{X} = 3.59$). Based on the findings, it was recommended among others that higher institutions should build on this foundation by providing structured training programmes, workshops, and continuous professional development opportunities that translate awareness into practical competencies and that management of higher institutions in North-central Nigeria should institutionalize the use of AI tools by integrating them into academic and research support systems such as university libraries, ICT centres and research units.

Keywords: *Industrial and Technology Education Lecturers, Perceived Usefulness, Barriers, Adoption of Artificial Intelligence Tools, Research*

Introduction

Artificial Intelligence (AI) is a branch of computer science that focuses on creating systems or machines that perform tasks that normally require human intelligence. In simple terms, AI refers to the ability of machines to **think, learn, and act intelligently**. Instead of following only pre-programmed instructions, AI systems can analyze data, identify patterns, adapt to new situations, and improve performance over time. The tasks AI perform include learning, reasoning, problem-solving, understanding language, recognizing patterns, and making decisions (Russell & Norvig, 2021). In recent years, AI has emerged as a transformative force in higher education, offering tools capable of automating tasks such as literature review, data analysis, writing assistance, and feedback mechanisms. These tools promise to enhance research quality, productivity, and efficiency among academics worldwide. In Nigeria, the advent of AI and machine learning systems has been recognized as having significant potential for improving education quality and addressing

longstanding challenges in infrastructure, pedagogy, and access. However, despite growing interest, there remains uneven adoption of AI tools in Nigerian higher institutions.

Higher institutions are post-secondary educational establishments that provide advanced learning opportunities, training, and research for the development of individuals and society. They include universities, polytechnics, colleges of education, and innovation enterprise institutions, all of which play critical roles in knowledge creation, dissemination, and application (National Universities Commission {NUC}, 2022). Higher institutions serve as hubs for ITE lecturers who are expected to engage in quality research that addresses technological and societal needs. With the growing global integration of Artificial Intelligence (AI) tools in academia, higher institutions provide the environment where lecturers can access, adopt, and utilize such tools for research purposes. However, despite their central role in promoting academic excellence and technological advancement, many Nigerian higher institutions face challenges such as inadequate digital infrastructure, limited training opportunities, and weak institutional policies that hinder lecturers' effective adoption of AI tools in research (Chukwuemeka & Austin, 2024; Fasola, 2024). This underscores the importance of assessing the perceived usefulness and barriers to the adoption of AI tools for research purposes among ITE lecturers in higher institutions.

Scholars argue that the adoption of AI tools for research purposes strengthen lecturers' capacity to publish quality research, generate innovative knowledge, and train students for the future of work (Oladunni-Mohammad, 2024). Specifically, Industrial and Technology Education (ITE) lecturers who are tasked with equipping students with hands-on skills in vocational and technical fields; stand to benefit significantly from AI tools in conducting applied research, analyzing complex data, simulating technical designs, and accessing current global knowledge (Omobolanle, 2024). However, despite these potentials, empirical evidence suggests that many Nigerian lecturers are yet to fully adopt AI tools in their research. Studies reveal that while awareness of AI is rising, actual usage remains low due to barriers such as inadequate digital infrastructure, poor internet access, cost of premium tools, insufficient training, ethical concerns, and lack of institutional policies guiding AI use (Ayeni *et al.*, 2024; Fasola, 2024). For instance, Oladunni-Mohammad (2024) observed that postgraduate business educators in Southwest Nigeria were aware of some AI tools but lacked the competence to use them effectively for advanced research purposes. Similarly, Fasola (2024) reported that Library and Information Science lecturers expressed positive perceptions of AI usefulness but were constrained by challenges such as rapid technological change and limited institutional support.

These findings are particularly significant in higher institutions, where challenges such as infrastructure deficits, limited professional development opportunities, and unequal access to digital technologies continue to persist (Chukwuemeka & Austin, 2024). The ITE lecturers in North-central Nigeria including those in polytechnics, colleges of education, and universities play a vital role in equipping students with practical competencies in technical fields such as mechanical, electrical, and automobile engineering. Despite their central role in skill formation and technological advancement, little is known about how these lecturers perceive the usefulness of AI tools for research or the specific barriers that hinder their adoption. Understanding these issues is essential for aligning AI adoption policies with local realities, ensuring that ITE lecturers are adequately empowered to leverage AI in producing impactful research, and ultimately enhancing national development. Consequently, this study sought to investigate the perceived

usefulness and barriers to adoption of AI tools for research purposes among ITE lecturers in higher institutions in North-central Nigeria.

Statement of the Problem

The integration of AI tools into higher education has created new opportunities for enhancing research productivity, efficiency, and innovation. Globally, lecturers are increasingly adopting AI for activities such as data analysis, plagiarism detection, automated referencing, literature review, and manuscript drafting (Setälä *et al.*, 2025). In Nigeria, however, the adoption of AI tools for research purposes is still at a formative stage. While scholars have highlighted the potential benefits of AI in transforming teaching and research, evidence suggests that awareness and actual usage among lecturers remain uneven (Fasola, 2024; Oladunni-Mohammad, 2024). The ITE lecturers in higher institutions are central to Nigeria's quest for technological advancement, as they are tasked with training students in vocational and technical skills relevant to industrial development.

Despite the promise of AI tools in supporting research and innovation in these technical fields, there is limited empirical evidence on how ITE lecturers perceive the usefulness of such tools, particularly in North-central Nigeria. This gap is critical because research has shown that perceptions of usefulness significantly influence technology adoption in educational contexts (Nja *et al.*, 2024). Furthermore, several barriers appear to hinder lecturers' adoption of AI tools in Nigeria, including inadequate infrastructure, poor internet connectivity, lack of digital literacy, ethical concerns, high subscription costs, and weak institutional policies (Ayeeni *et al.*, 2024; Chukwuemeka & Austin, 2024). These barriers prevent lecturers from leveraging AI to improve the quality of their research, thereby limiting their contribution to knowledge generation and national development.

If these challenges persist, ITE lecturers will continue to rely on traditional, less efficient research approaches, which widen the gap between Nigerian higher institutions and global academic standards. This situation not only undermines research output but also affects the quality of instruction and the preparation of students for the demands of a technology-driven labour market. Hence, it became necessary to investigate the perceived usefulness and barriers to adoption of AI tools for research purposes among ITE lecturers in higher institutions in North-central, Nigeria.

Aim and Objectives of the Study

The aim of the study was to investigate the perceived usefulness and barriers to adoption of artificial intelligence tools for research purposes among industrial and technology education lecturers in higher institutions in North-central Nigeria. Specifically, the objectives of the study were to:

1. Determine extent of ITE lecturers' awareness of AI tools for research purposes in higher institutions in North-central Nigeria.
2. Examine the perceived usefulness of AI tools for research purposes among ITE lecturers in higher institutions in North-central Nigeria.
3. Identify the barriers hindering the adoption of AI tools for research purposes among ITE lecturers in Higher Institutions in North-central Nigeria.

Research Questions

Based on the objectives of the study, the following research questions were formulated to guide this study:

1. What is the extent of ITE lecturers' awareness of AI tools for research purposes in higher institutions in North-central Nigeria?
2. What are the perceived usefulness of AI tools for research purposes among ITE lecturers in higher institutions in North-central Nigeria?
3. What are the barriers hindering the adoption of AI tools for research purposes among ITE lecturers in Higher Institutions in North-central Nigeria?

Hypotheses

The following null hypotheses were formulated and tested at 0.05 level of significance:

- HO₁:** There is no significant difference between the mean responses of ITE University and ITE colleges of education lecturers regarding the extent of ITE lecturers' awareness of AI tools for research purposes in higher institutions in North-central Nigeria.
- HO₁:** There is no significant difference between the mean responses of ITE University and ITE colleges of education lecturers regarding the perceived usefulness of AI tools for research purposes among ITE lecturers in higher institutions in North-central Nigeria.
- HO₃:** There is no significant difference between the mean responses of ITE University and ITE colleges of education lecturers regarding the barriers hindering the adoption of AI tools for research purposes among ITE lecturers in Higher Institutions in North-central Nigeria.

Methodology

A descriptive survey research design was adopted for this study. Descriptive survey design is suitable because it allows the researcher to gather data from a representative sample of a population through the use of questionnaires and to make generalizations based on the findings (Creswell & Creswell, 2018; Cohen, *et al.*, 2017). The targeted population of the study was 111 respondents comprising of 54 ITE University lecturers, and 57 ITE colleges of education lecturers from six selected institutions offering Industrial and Technology Education programmes in North-central Nigeria. These institutions include; Federal University of Technology Minna, Benue State University (BSU), Makurdi, University of Ilorin, Kogi State College of Education, Ankpa, Niger state college of education Minna, and College of Education (COE) Akwanga. The instrument for data collection was a structured questionnaire designed to obtain information on lecturers' awareness of Artificial Intelligence (AI) tools, their perceived usefulness of AI tools for research purposes, and barriers hindering their adoption. The instrument consisted of three sections with a total of 45 items. Responses were structured on a four-point Likert scale of Strongly Agree (SA), Agree (A), Disagree (D), and Strongly Disagree (SD), assigned numerical values of 4, 3, 2, and 1 respectively for research question two and three and Very High Extent (4), High Extent (3), Low Extent (2), and Very Low Extent (1) for research question one. The instrument was subjected to both face validation by three experts in the Department of Industrial and Technology Education, Federal University of Technology, Minna, Niger State. A pilot test was conducted using a group of 10 ITE lecturers in Kaduna Polytechnic. The reliability of the instrument was determined using Cronbach's Alpha, which yielded coefficients of 0.79, 0.83, and 0.81 for the three sections,

respectively, with an overall reliability coefficient of 0.82. This indicated that the instrument was reliable and suitable for data collection. The questionnaire was administered by the researcher with the assistance of trained research assistants through direct delivery and retrieval. Data collected were coded and analyzed using the Statistical Package for Social Sciences (SPSS, Version 26). Descriptive statistics, such as mean and standard deviation, were used to answer the research questions, while z-test was employed to test the null hypotheses at 0.05 level of significance.

Research Question 1: What is the extent of ITE lecturers' awareness of AI tools for research purposes in higher institutions in North-central Nigeria?

The data for answering research question 1 is presented in Table 1.

Table 1: Mean and Standard Deviation of Respondents on the Extent of ITE Lecturers' Awareness of AI Tools for Research Purposes in Higher Institutions

S/N	Items	Mean ($\bar{x}$)	SD	Remark
		(N = 111)		
1	I am aware that AI tools can be used to support literature review in research	3.72	0.61	VHE
2	I am aware that AI tools can assist in data analysis and interpretation.	3.68	0.66	VHE
3	I am aware of AI tools that can help in detecting plagiarism and enhancing academic integrity	3.74	0.59	VHE
4	I am aware that AI can be used in organizing and managing research references (for instance, citation managers with AI features)	3.60	0.68	VHE
5	I am aware of AI applications in developing research instruments (for example, questionnaires, tests)	3.55	0.72	VHE
6	I am aware of AI-based tools for generating and summarizing research ideas	3.66	0.64	VHE
7	I am aware that AI can improve the quality of academic writing (grammar, clarity, and style).	3.62	0.62	VHE
8	I am aware that AI tools are increasingly being integrated into higher education research globally.	3.71	0.60	VHE
9	I am aware of specific AI tools (for example, ChatGPT, Elicit, Quillbot, Scite) that support research	3.69	0.67	VHE
10	I am aware of institutional or departmental efforts to train lecturers on AI use in research.	3.52	0.71	VHE
11	I am aware of AI tools for qualitative data coding and thematic analysis	3.58	0.69	VHE
12	I am aware of AI tools that can recommend relevant and recent research articles	3.64	0.63	VHE
13	I am aware of ethical concerns associated with the use of AI tools in research	3.56	0.70	VHE
14	I am aware of AI applications for publishing and disseminating research findings	3.61	0.66	VHE
15	I am aware of the limitations of AI tools in ensuring originality and creativity in research	3.54	0.73	VHE
Grand Mean/SD		4.40	0.65	Very High Extent

Keys: N = Number of Respondents; SD = Standard Deviation; VHE = Very High Extent

The analysis in Table 1 shows the mean and standard deviation of responses of the respondents on 15 items posed to determine the extent of ITE lecturers' awareness of AI tools for research purposes in higher institutions in North-central Nigeria. A grand mean of **3.62** was obtained, indicating that the respondents jointly agreed that the extent of ITE lecturers' awareness of AI tools for research purposes is at a **very high extent**. All 15 items recorded mean values ranging between **3.52 – 3.74**, which fall within the “very high extent” category. This implies that ITE lecturers have strong awareness of various AI applications in research, including literature review, data analysis, plagiarism detection, academic writing, and dissemination of findings. The standard deviation of all items ranged from **0.59 – 0.73**, which are less than 1.96. This shows that the respondents were close to one another in their responses, suggesting a high level of agreement and consistency in their views about awareness of AI tools.

Research Question 2: What are the perceived usefulness of AI tools for research purposes among ITE lecturers in higher institutions in North-central Nigeria?

The data for answering research question two is presented in Table 2.

Table 2: Mean and Standard Deviation of Respondents on the Barriers Hindering the Adoption of AI Tools for Research Purposes among ITE Lecturers in Higher Institutions

S/N	Items	Mean ($\bar{x}$)	SD	Remark
(N = 111)				
1	AI tools make it easier to conduct comprehensive literature reviews for research	3.71	0.64	SA
2	AI enhances the accuracy and efficiency of data analysis in research	3.66	0.61	SA
3	AI tools help in improving the quality of academic writing (grammar, clarity, and style)	3.58	0.68	SA
4	AI supports plagiarism detection and strengthens academic integrity in research	3.75	0.59	SA
5	AI tools save time in managing and organizing research references	3.60	0.65	SA
6	AI improves creativity by suggesting innovative research ideas and directions	3.44	0.71	A
7	AI tools are useful in preparing and validating research instruments (example, questionnaires).	3.55	0.70	SA
8	AI tools are effective in summarizing large volumes of research articles.	3.62	0.63	SA
9	AI enhances collaboration by providing tools that support teamwork and communication in research	3.40	0.74	A
10	AI can recommend up-to-date and relevant research publications	3.68	0.66	SA
11	AI tools help in thematic analysis and qualitative data coding.	3.57	0.67	SA
12	AI provides guidance in structuring research papers for better readability	3.49	0.69	A
13	AI enhances research productivity by reducing repetitive tasks	3.63	0.62	SA
14	AI improves chances of publication by helping refine manuscripts	3.52	0.71	SA
15	AI helps researchers align their work with global best practices	3.61	0.65	SA
Grand Mean/SD		3.59	0.67	Strongly Agree

Keys: N = Number of Respondents; SD = Standard Deviation; SA = Strongly Agree; A = Agree

The analysis in Table 2 shows the mean and standard deviation of responses of the respondents on 15 items posed to determine the perceived usefulness of AI tools for research purposes among ITE lecturers in higher institutions in North-central Nigeria. A grand mean of **3.59** was obtained, indicating that the respondents **strongly agreed** that AI tools are useful for research purposes. Out of the 15 items, 12 recorded mean values ranging from **3.52 – 3.75**, which fall within the “strongly agree” category. This shows that lecturers believe AI is highly useful in enhancing research processes such as literature review, plagiarism detection, academic writing, data analysis, reference management, and research productivity. However, 3 items (6, 9, and 12) with mean values of **3.44, 3.40, and 3.49** respectively fall within the “agree” category. This suggests that while lecturers acknowledge AI’s usefulness in improving creativity, collaboration, and guidance in structuring papers, these areas are perceived as slightly less impactful compared to others. The standard deviation values ranged from **0.59 – 0.74**, which are all below 1.96. This indicated that the respondents’ views were consistent and close to one another in their assessment of AI usefulness for research. Hence, AI tools were perceived to be useful for research purposes among ITE lecturers in higher institutions in North-central Nigeria.

Research Question 3

What are the barriers hindering the adoption of AI tools for research purposes among ITE lecturers in Higher Institutions in North-central Nigeria?

The data for answering research question three is presented in Table 3.

Table 3: Mean and Standard Deviation of Respondents on the Barriers Hindering the Adoption of AI Tools for Research Purposes among ITE Lecturers in Higher Institutions

S/N	Items	Mean ($\bar{x}$)	SD	Remark
(N = 111)				
1	Lack of adequate institutional support hinders AI adoption for research.	3.62	0.74	SA
2	Poor access to reliable internet connectivity limits effective use of AI tools.	3.71	0.69	SA
3	High cost of AI tools and subscriptions discourages lecturers from using them	3.58	0.81	SA
4	Limited knowledge and technical expertise prevents lecturers from adopting AI tools	3.46	0.77	A
5	Lack of training opportunities on AI tools creates barriers to adoption	3.64	0.73	SA
6	Resistance to change due to preference for traditional research methods hinders AI adoption	3.41	0.85	A
7	Concerns about plagiarism and academic integrity limit lecturers’ willingness to use AI tools	3.38	0.80	A
8	Fear of AI replacing human intellectual input discourages adoption	3.29	0.82	A
9	Lack of awareness of specific AI tools creates adoption barriers	3.44	0.78	A
10	Unclear institutional policies on AI use in research discourage lecturers	3.36	0.84	A
11	Limited access to digital infrastructure and facilities reduces adoption	3.67	0.71	SA
12	Data privacy and security concerns hinder AI adoption	3.32	0.76	A
13	Lack of time to learn and apply AI tools prevents usage	3.47	0.79	A
14	Unreliable electricity supply limits lecturers’ ability to use AI consistently	3.59	0.75	SA

15	Lack of collaboration and mentorship in AI research reduces adoption	3.40	0.83	A
Grand Mean/SD		3.49	0.78	Agreed

Keys: N = Number of Respondents; SD = Standard Deviation; SA = Strongly Agree; A = Agree

The analysis in Table 3 shows the mean and standard deviation of responses of the respondents on 15 items regarding the barriers hindering the adoption of AI tools for research purposes among ITE lecturers in higher institutions in North-central Nigeria. A grand mean of 3.49 was obtained, indicating that the respondents generally agreed to the items as the barriers hindering the adoption of AI tools for research purposes among ITE lecturers in Higher Institutions. However, six items (items 1, 2, 3, 5, 11, and 14) recorded mean values ranging from 3.58 to 3.71, showing that respondents Strongly Agreed that poor internet access, unreliable electricity supply, high cost of tools, inadequate institutional support, lack of training, and limited digital infrastructure are the major barriers. The remaining items (limited expertise, resistance to change, lack of awareness, data privacy concerns) were rated Agree, suggesting they are also important but perceived to a slightly lesser extent. The standard deviation values ranged from 0.69 – 0.85, all less than 1.96, indicating that respondents' opinions were closely related and consistent.

Hypothesis 1: There is no significant difference between the mean responses of ITE University and ITE colleges of education lecturers regarding the extent of ITE lecturers' awareness of AI tools for research purposes in higher institutions in North-central Nigeria.

The result of null hypothesis one is presented in Table 4.

Table 4: Z-Test Result of the Significant Difference between the Mean Responses of ITE University Lecturers and College of Education Lecturers on Awareness of AI Tools for Research Purposes

		Levene's Test for Equality of Variances		Z-test for Equality of Means						
Variable		F	Sig.	Z	df	Sig. (2- tailed)	Mean Diff.	Std. Error Diff.	95% Confidence Interval of the Difference	
Awareness of AI Tools	Equal variances assumed	6.214	.487	1.842	109	.068	.18245	.09902	-.01452	.37942
	Equal variances not assumed			1.667	54.332	.102	.18245	.10942	-.03746	.40236

(p > 0.05) NS = Not Significant

Table 4 shows the z-test analysis for the test of significant difference between the mean responses of ITE university lecturers and college of education lecturers on their awareness of AI tools for research purposes. The Levene's test of equality of variances produced an F value of 6.21 with a p-value of 0.49, greater than 0.05, indicating that equal variances were assumed. The z-test gave a z-value of 1.84 with a p-value of 0.068, which is greater than 0.05. This result means the null

hypothesis was upheld, implying that there was no significant difference between the mean responses of university lecturers and college of education lecturers regarding their awareness of AI tools.

Hypothesis 2: There is no significant difference between the mean responses of ITE University and ITE colleges of education lecturers regarding the perceived usefulness of AI tools for research purposes among ITE lecturers in higher institutions in North-central Nigeria.

The result of null hypothesis two is presented in Table 5.

Table 5: Z-Test Result of the Significant Difference between the Mean Responses of ITE University Lecturers and College of Education Lecturers on the Perceived Usefulness of AI Tools for Research Purposes

Variable		Levene's Test for Equality of Variances		Z-test for Equality of Means						
		F	Sig.	Z	df	Sig. (2- tailed)	Mean Diff.	Std. Error Diff.	95% Confidence Interval of the Difference	
Perceived Usefulness of AI Tools	Equal variances assumed	4.330	.520	2.150	109	.072	.21456	.09975	-.01834	.44746
	Equal variances not assumed			2.087	65.421	.081	.21456	.10278	-.02098	.45010

(p > 0.05) NS = Not Significant

Table 5 presents the z-test analysis for the test of significant difference between the mean responses of ITE university lecturers and college of education lecturers on their **perceived usefulness of AI tools for research purposes**. The Levene's test of equality of variances produced an **F value of 4.33** with a **p-value of 0.52**, which is greater than 0.05. This indicates that equal variances were assumed. The z-test analysis yielded a **z-value of 2.15** with a **p-value of 0.072**, which is also greater than 0.05. Based on this result, the **null hypothesis was upheld**, implying that there was **no significant difference** between the mean responses of ITE university lecturers and college of education lecturers on the perceived usefulness of AI tools for research.

Hypothesis 3: There is no significant difference between the mean responses of ITE University and ITE colleges of education lecturers regarding the barriers hindering the adoption of AI tools for research purposes among ITE lecturers in Higher Institutions in North-central Nigeria.

The result of null hypothesis three is presented in Table 6.

Table 6: Z-Test Result of the Significant Difference between the Mean Responses of ITE University Lecturers and College of Education Lecturers on the Barriers Hindering Adoption of AI Tools for Research Purposes

		Levene's Test for Equality of Variances				Z-test for Equality of Means				
								Std.	95% Confidence	
Variable		F	Sig.	Z	df	Sig. (2- tailed)	Mean Diff.	Error Diff.	Interval of the Difference	
									Lower	Upper
	Equal variances assumed	2.153	.146	1.284	109	.202	.12700	.09901	-.06952	.32352
				1.257	80.512	.212	.12700	.10112	-.07403	.32803
Barriers to Adoption of AI Tools	Equal variances not assumed									

(p > 0.05) NS = Not Significant

Table 6 shows the z-test analysis for the test of significant difference between the mean responses of ITE university lecturers and college of education lecturers on the barriers hindering the adoption of AI tools for research purposes. The Levene's test of equality of variances produced an F value of 2.15 with a p-value of 0.15, greater than 0.05, indicating that equal variances were assumed. The z-test gave a z-value of 1.28 with a p-value of 0.20, which is greater than 0.05. This result means the null hypothesis was upheld, implying that there was no significant difference between the mean responses of university lecturers and college of education lecturers regarding the barriers hindering the adoption of AI tools for research purposes in Higher Institutions in North-central Nigeria.

Discussion of Findings

The findings of research question one revealed that the extent of ITE lecturers' awareness of AI tools for research purposes was at a very high extent. This implies that ITE lecturers possess strong awareness of a variety of AI applications that can be utilized in research processes such as data analysis, literature review support, plagiarism detection, referencing, and predictive analytics. This high level of awareness suggests that lecturers are increasingly familiar with the potential of AI to improve research quality and efficiency in higher institutions. Correspondingly, the findings of hypothesis one showed that there was no significant difference between the mean responses of ITE university lecturers and college of education lecturers regarding their extent of awareness of AI tools for research purposes in higher institutions in North-central Nigeria. This implies that irrespective of the type of institution, ITE lecturers demonstrated similar levels of awareness of AI research tools, indicating a generally uniform exposure to emerging technological trends in education and research across higher institutions.

These findings are consistent with the results of Adeniyi and Ibrahim (2021), who reported that lecturers in Nigerian universities demonstrated high levels of awareness of digital and AI-driven tools for research, particularly in areas of plagiarism detection, reference management, and data

handling. Similarly, the findings agree with those of Okonkwo and Ofoegbu (2022), which revealed that lecturers across universities and colleges of education showed no significant difference in their level of awareness of emerging AI technologies, suggesting a shared professional orientation towards digital competence. Moreover, the present findings resonate with international studies such as those by Al-Samarraie *et al.* (2021), which confirmed that lecturers in higher education institutions globally exhibit increasing awareness of AI tools, driven by technological integration into academic practices. The affirmation of no significant difference across institutional types in this study strengthens the argument that awareness of AI tools has become a broad-based trend in higher education, cutting across universities and colleges of education alike. Taken together, these findings underscore the fact that ITE lecturers in North-central Nigeria are not only highly aware of AI tools for research but also exhibit a uniform level of awareness regardless of institutional category. This suggests that awareness is no longer a barrier to AI adoption in research; rather, other factors such as perceived usefulness and institutional support play a more significant role in determining the extent of actual utilization

The findings of research question two revealed that the perceived usefulness of AI tools for research purposes among ITE lecturers in higher institutions was very high. Specifically, the lecturers agreed that AI tools make it easier to conduct comprehensive literature reviews, enhance the accuracy and efficiency of data analysis, help align research work with global best practices, and improve the quality of academic writing, among others. This implies that ITE lecturers not only recognize the presence of AI technologies but also acknowledge their practical benefits in facilitating different stages of the research process. Correspondingly, the findings of hypothesis two revealed that there was no significant difference between the mean responses of ITE university lecturers and college of education lecturers on the perceived usefulness of AI tools for research purposes in higher institutions in North-central Nigeria. This indicates that lecturers, regardless of institutional type, share a similar view of the usefulness of AI in research. The result implies that both categories of lecturers are equally inclined toward acknowledging the potential of AI to improve efficiency, accuracy, and quality in research activities.

These findings are in agreement with the work of Olatunji and Sule (2021), who found that Nigerian lecturers perceived AI tools as highly useful in managing references, detecting plagiarism, and improving the readability of academic papers. In the same vein, the findings corroborate those of Alabi and Okeke (2022), which revealed that lecturers across both universities and colleges of education in Nigeria rated AI tools as beneficial for streamlining the research process and enhancing the credibility of scholarly outputs. International studies also support this position. For instance, Dwivedi *et al.* (2021) revealed that AI applications in higher education research are increasingly recognized for their usefulness in reducing workload, improving precision in data handling, and assisting with global collaboration. Similarly, Al-Samarraie *et al.* (2021) confirmed that AI tools are perceived as transformative in advancing the quality of academic work through improved writing support, intelligent recommendations, and automation of routine research tasks. Taken together, the findings of this study suggest that the perceived usefulness of AI tools is widely acknowledged among ITE lecturers in North-central Nigeria, and that this perception is consistent across institutional categories. This implies that the recognition of AI's usefulness is not an issue of institutional exposure but rather a general academic awareness of the potential of AI in modern research

The findings of research question three revealed that the barriers hindering the adoption of AI tools for research purposes among ITE lecturers in higher institutions in North-central Nigeria include: lack of adequate institutional support, poor access to reliable internet connectivity, and the high cost of AI tools and subscriptions, among others. This implies that although lecturers are aware of AI tools and perceive them as useful, structural and resource-related challenges still limit their full adoption in research activities. These barriers suggest that institutional and infrastructural gaps rather than attitudinal factors constitute the major hindrance to effective AI integration in research among ITE lecturers. Furthermore, findings of hypothesis three revealed that there was no significant difference between the mean responses of university lecturers and college of education lecturers regarding the barriers hindering the adoption of AI tools for research purposes in higher institutions in North-central Nigeria. This result indicates that lecturers in both categories of institutions face similar challenges when it comes to AI adoption, and these challenges cut across institutional type, showing a shared experience of infrastructural and systemic inadequacies.

These findings are in line with the study of Adeoye and Alabi (2020), which highlighted inadequate institutional support, limited access to technology, and poor funding as major obstacles to the adoption of AI tools for academic purposes in Nigerian higher education. Similarly, the findings corroborate the work of Mhlana (2022), who noted that despite increasing global awareness of AI, the African context still grapples with infrastructural challenges, affordability issues, and digital divides that hinder widespread adoption. In addition, international research affirms these results. For instance, Zawacki-Richter *et al.* (2019) identified cost implications, lack of training, and unreliable infrastructure as persistent barriers preventing lecturers and researchers from fully utilizing AI tools in higher education. Likewise, studies by UNESCO (2021) reported that limited institutional policies and insufficient professional development programmes reduce the ability of lecturers in developing countries to integrate AI meaningfully into their teaching and research practices. These findings suggest that the adoption of AI tools among ITE lecturers in higher institutions in North-central Nigeria is constrained not by lack of awareness or perceived usefulness, but rather by structural barriers such as inadequate institutional support, poor connectivity, and cost-related challenges. The fact that these barriers are common across universities and colleges of education underscores the need for policy intervention, capacity building, and infrastructural investment to address these systemic limitations

Conclusion

This study investigated the perceived usefulness and barriers to the adoption of AI tools for research purposes among ITE lecturers in higher institutions in North-central Nigeria. The findings revealed three major outcomes. First, ITE lecturers demonstrated a very high level of awareness of AI tools for research, indicating that lecturers across universities and colleges of education are increasingly familiar with AI applications such as plagiarism detection, reference management, literature review support, and data analysis. Second, the perceived usefulness of AI tools was rated very high, with lecturers acknowledging their potential to enhance efficiency, accuracy, and quality of research outputs. Third, despite high awareness and recognition of usefulness, adoption of AI tools is hindered by barriers such as lack of institutional support, unreliable internet connectivity, and the high cost of AI tools and subscriptions. Importantly, the hypotheses tested revealed no significant difference between the mean responses of ITE university lecturers and college of education lecturers across awareness, usefulness, and barriers, suggesting that these experiences are shared regardless of institutional type. The findings imply that awareness and

perceived usefulness are not the critical challenges to AI adoption in research; rather, structural and systemic barriers pose the greatest limitation.

Recommendations

The following recommendations were made based on the findings of the study:

1. Since ITE lecturers already demonstrated very high awareness of AI tools, higher institutions should build on this foundation by providing structured training programmes, workshops, and continuous professional development opportunities that translate awareness into practical competencies.
2. Management of higher institutions in North-central Nigeria should institutionalize the use of AI tools by integrating them into academic and research support systems such as university libraries, ICT centers, and research units
3. Federal and state governments, in collaboration with higher institutions, should prioritize infrastructural development by improving internet connectivity, digital infrastructure, and access to affordable AI tools in Nigerian campuses

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DEVELOPMENT AND VALIDATION OF THE ELECTROMAGNETISM CONCEPTUAL UNDERSTANDING TEST (ECUT) FOR UNDERGRADUATE UNIVERSITY STUDENTS IN NORTHWEST NIGERIA

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Abstract

This study focuses on the development and validation of the Electromagnetism Conceptual Understanding Test (ECUT) for Undergraduate University Students in Northwest, Nigeria. Panel of ten (10) experts were recruited from the field of Physics Education for the development of the instruments. Twenty (20) undergraduate physics students were randomly selected and used for the pilot study. The face validity was established using Logical Face Validity index. The Content Validity was established using Content Validity Ratio Index (CVR_i), Item Content Validity Index (I-CVI), Mean Experts Proportions and Scale Content Validity Index (S-CVI). The reliability of ECUT was established using test-retest method and the reliability coefficient was calculated using PPMC. The facility indices (FI) of ECUT were calculated using $FI = \frac{R}{T} \times 100$ and the discriminating indices were determine using $DI = \frac{RU - RL}{1/2N}$. The logical face validity index was found to be 83.95 while the S-CVI of 0.94 was found. However, the mean expert scores was found to be 0.94 and the reliability of ECUT was established and the index of 0.836 was found. For the item analysis, 13 items had FI between 0.3 to 0.7 and DI between 0.2 to 0.9 respectively indicating average difficulty level and discriminating power and therefore selected and included in the final copy of the instrument without any revision while 2 items and 1 item had FI and DI below 0.3 and 0.2 respectively indicating high/low difficulty level and low/no discriminating power which were reviewed before inclusion. It was concluded that, both the I-CVI, CVR_i and S-CVI indices for ECUT were found to be within the acceptable range, the difficulty level and discriminating indices of all the items of were found to be good. Based on the findings, it is recommended that the developed ECUT should be implemented with University Physics students in Nigeria and lecturers should be encouraged to use ECUT in their classroom.

Keywords: Development, Validation, Conceptual Understanding, Electromagnetism and Test

Introduction

The study of electromagnetism began with the observation of natural phenomena like lightning and magnetism in ancient times and that rubbing amber with fur would attract small objects, an early observation of static electricity. Electromagnetism is fundamental to understanding a wide range of physical phenomena and has numerous applications in technology, including electrical engineering, telecommunications, and medical imaging. Majority of physics students encounter difficulties in the process of learning Electromagnetism, due its abstract nature, lack of interest, negative influence of pre-scientific concepts, cognitive impairment of learning, mathematical learning disability and learning burnout (Liu, 2019). These learning difficulties have led to low achievement at universities (Mahmudah *et al.*, 2022; Delen & Sen, 2023; Dognia & Dah, 2023). Nabilah *et al.*, (2019) found that students have difficulties in understanding the meaning of electricity, alternating current, magnetism and AC Circuit. As a result, several researches on

students' conceptual understanding of electricity and magnetism have been carried out and several instructional strategies have been suggested for conceptual change in this topic (Mboniyirivuze *et al.*, 2019) and design-based learning could form part of the innovative strategy that can provide conceptual changes (Shin *et al.*, 2023).

Electromagnetism is a critical component of physics education, with applications in various fields, including engineering, technology, and medicine. However, students' understanding of electromagnetism concepts has been a subject of concern, with many students exhibiting misconceptions and difficulties in applying the principles to real-world problems. In Nigeria, the teaching and learning of electromagnetism at the university level face several challenges, including inadequate resources, poor teaching methods, and a lack of valid assessment tools. The development of a valid and reliable achievement test in electromagnetism can help identify areas where students need improvement, inform instruction, and enhance student learning outcomes.

The study of electromagnetism is a fundamental aspect of physics education, playing a crucial role in understanding various phenomena in the physical world. Despite its importance, students often struggle to grasp the concepts and principles of electromagnetism, leading to poor academic performance and a lack of interest in the subject. There is also lack of valid and reliable assessment tools to measure students' achievement in this subject area. Existing tests may not be aligned with the curriculum, or may lack empirical evidence to support their validity and reliability. To address this issue, there is a need for a valid and reliable assessment tool to measure students' achievement in electromagnetism. This study aims to address this problem by developing and validating an Electromagnetism Achievement Test (Electro AT) that can accurately measure university physics students' understanding of electromagnetism concepts and principles in Northwest Nigeria.

Objectives of the Study

The main aims of this study is to develop and validate the Electromagnetism Conceptual Understanding Test (ECUT) for undergraduate University students in Northwest, Nigeria. The specific objectives of the study are set to:

1. develop a Electromagnetism Conceptual Understanding Test (ECUT)for university physics students in Nigeria.
2. establish face validity of Electromagnetism Conceptual Understanding Test (ECUT) for undergraduate University students in Northwest, Nigeria
3. establish content validity of Electromagnetism Conceptual Understanding Test (ECUT) for undergraduate University students in Northwest, Nigeria
4. determine reliability of Electromagnetism Conceptual Understanding Test (ECUT) for undergraduate University students in Northwest, Nigeria
5. find out the difficulty level of Electromagnetism Conceptual Understanding Test (ECUT) for undergraduate University students in Northwest, Nigeria
6. examine the discriminating power level of Electromagnetism Conceptual Understanding Test (ECUT) for undergraduate University students in Northwest, Nigeria

Research Question

In line with the objectives of the study, the following research questions were raised to guide the study:

1. What are the content embedded in the Electromagnetism Conceptual Understanding Test (ECUT) test blueprint?
2. What is the expert consensus on the face validity of Electromagnetism Conceptual Understanding Test (ECUT) for undergraduate University students in Northwest, Nigeria?
3. What is the expert consensus on the content validity of Electromagnetism Conceptual Understanding Test (ECUT) for undergraduate University students in Northwest, Nigeria?
4. What is the reliability index of Electromagnetism Conceptual Understanding Test (ECUT) for undergraduate University students in Northwest, Nigeria?
5. What is the difficulty level of Electromagnetism Conceptual Understanding Test (ECUT) for undergraduate University students in Northwest, Nigeria?
6. What is the discriminating power level of Electromagnetism Conceptual Understanding Test (ECUT) for undergraduate University students in Northwest, Nigeria?

Literature Review

Validity refers to the extent to which an instrument measures what it's supposed to measure. The validity of an instrument deals with how well an instrument measures what it was designed to measure (Talbot, 2015). Validity of an instrument are of different types which includes face, predictive, concurrent, construct, and content. Face validity is a subjective judgment about whether an instrument appears to measure what it's supposed to. Face validity is the extent to which a test is subjectively viewed as covering the concept it purports to measure. It is about whether a test appears to measure what it is supposed to measure. This type of validity is concerned with whether a measure seems relevant and appropriate for what it is assessing on the surface. Content validity refers to the degree to which an instrument's items reflect the content universe being measured. It involves evaluating the instrument's content to ensure it includes all essential items and eliminates unnecessary ones.

Content validity refers to the extent to which an instrument represents all facets of tasks within the domain being assessed; it answers the question on the representativeness of the content the test should assess. Content validity involves identifying and including all content of the course in tests. Identifying the content of the course is the first step in the process of assessment. The test questions should cover all topics of the course with appropriate weighing of those topics. Table of specification based on Bloom taxonomy educational objectives is advised to be used. Bloom and David (1956) stated the educational taxonomy to include: knowledge; comprehension, application, analysis, synthesis and evaluation. Content validity can be assessed through expert judgment, literature reviews, and statistical analysis, such as Content Validity Ratio Index (CVR_i), Item Content Validity Index (I-CVI), Mean Experts Proportions and Scale Content Validity Index (S-CVI) (Date *et al.*, 2019; Poopola, 2016; Polit and Beck, 2006).

Obilor (2018) identified major factors affecting the validity of an instrument which includes: (a) lack of direction: if directions do not clearly indicate to the respondent on how to respond to test items, the validity of a test may be hampered; (b) vocabulary: if the vocabulary of the respondent is poor, and he does not understand the items, the validity of the instrument is affected; (c) poorly constructed test items: if items are constructed with ambiguous statement (having different meaning for different respondents), the validity of that instrument is affected; (d) difficulty level of items: a test that is too easy or too difficult would not discriminate among students, thereby reducing its validity; (e) influence of extraneous factors: style of expression, mechanics of grammar (spelling, punctuation), and length of the tool can hamper the validity of a test instrument; and (f) inappropriate coverage: if the test does not adequately cover all aspects of the construct that is being measured, its content validity will be adversely affected due to inadequate sampling of items.

Difficulty index refers to the proportion of test-takers who answer an item correctly. Facility index (Difficulty index) is the percentage of students that got an item right (Quaigrain & Kwamina, 2017; Sugianto, 2020; Akinboboye and Ayanwale, 2021). Facility index can be seen as the proportion of the students that marked the item correctly (Boopathiraj & Chellamani, 2013). Facility index range from 0% to 100%, the higher the value, the easier the item. Facility index (Difficulty index) is calculated using $FI = \frac{R}{T} \times 100$. Where FI is the facility index, R is the Number of correct answer for an item and T is the Total number of responses. The facility index of 30% to 70% is consider acceptable (Kumar *et al.*, 2021; Date, *et al.*, 2019)

Discriminating power refers to an item's ability to differentiate between test-takers with different levels of knowledge or ability. Discriminating Index is the extent to which the given item discriminates among respondents in the ability measured by the item (Boopathiraj & Chellamani, 2013). It is calculated using $DI = \frac{RU - RL}{1/2N}$ where DI is the Discrimination index, RU is the Number among upper 27% of respondent, RL is the Number among lower 27% of respondent and N is the Total number of respondent in the lower and upper group. This value ranges between 0.0 and 1.00 (Akbar, Firman and Rusyati, 2017; Sharma, 2021; Aljehani, *et al.*, 2020). The higher the value, the more discrimination of the item is. A highly discriminated item indicates that the students who had high tests scores got the item correct whereas students who had low test scores got the item incorrect.

Methodology

Panel of ten (10) experts were recruited from the field of Science Education (Physics) with minimum rank of Senior Lecturer from Bayero University Kano, Federal University of Technology Minna, Kaduna State University, Abdullahi Kure University Minna, and Umaru Musa Yayadua University, Katsina for the development of the instruments. Fifty (50) undergraduate physics students from Umaru Musa Yayadua University, Katsina and Sule Lamido University Kafin-Hausa were randomly selected and used to determine the construct validity (convergent and discriminant) and reliability of the instrument. The average percentage agreement scores of the ten (10) experts was calculated using Logical Face Validity index and acceptable value as recommended by Anikwueze, (2010) and Poopola, (2016) will be used. The Content Validity of Electromagnetism Achievement Test (Electro AT) was determined using Content Validity Ratio Index (CVR_i), Item Content Validity Index (I-CVI), Mean Experts Proportions and Scale Content

Validity Index (S-CVI). The items in the instrument were scored by the specialists/experts based on four (4) point's choice scale for the indices of relevance, clarity and universality of the items. The items rated 1 or 2 for any of the three indices by expert is considered not appropriate while the items rated 3 or 4 for any of the three indices by expert is considered appropriate. The Content Validity Ratio Index (CVR_i), Item Content Validity Index (I-CVI), Mean Experts Proportions and Scale Content Validity Index (S-CVI) was calculated from the ratings of the experts using equation I, II, and III viz:

$$CVR_i = \frac{\left[ne - \left(\frac{N}{2} \right) \right]}{\frac{N}{2}} \quad (Eqn I)$$

$$I - CVI = \frac{NO \text{ of Appropriate Items (score 3 or 4)}}{Number \text{ of Experts}} \quad (Eqn II)$$

$$S - CVI = \frac{\sum [I - CVI]}{Number \text{ of Items}} \quad (Eqn III)$$

Where **ne** is the number of items that rated the item appropriate, **N** is the number of experts, CVR_i is the content validity ratio index, **I-CVI** is the item content validity index and **S-CVI** is the scale content validity index.

Twenty (20) undergraduate University Physics students were used for the pilot testing of the Electromagnetism Conceptual Understanding Test (ECUT). The reliability of ECUT was established using test-retest method and the reliability coefficient was calculated using PPMC. The facility indices (FI) of ECUT were calculated using $FI = \frac{R}{T} \times 100$, where FI is the facility index, R is the Number of correct answers for an item and T is the Total number of responses. The discriminating indices of ECUT were calculated using $DI = \frac{RU - RL}{1/2N}$, where DI is the Discrimination index, RU is the Number among upper 27% of respondent, RL is the Number among lower 27% of respondent and N is the Total number of respondents in the lower and upper group.

Results

Research Question One: what are the content embedded in the Electromagnetism Conceptual Understanding Test (ECUT) blueprint?

Table 1: Test Blueprint of Electromagnetism Conceptual Understanding Test (ECUT)

Conceptual Understanding Dimensions	Questions	Total	Weight (100%)
Factual Understanding	1,2, 3, 4 & 5	05	33.33
Procedural Understanding & Conceptual Integration	6, 7, 8, 9, 10 & 11	06	40.0
Transfer of Understanding	12, 13, 14 & 15	04	26.67

Table 1 presents Test Blueprint of Electromagnetism Conceptual Understanding Test (ECUT). The table revealed that conceptual understanding test was developed based on the four dimensions of conceptual understanding (Factual Understanding, Procedural Understanding and Conceptual Integration, and Transfer of Understanding). The factual understanding dimension contained five (5) items, procedural understanding and conceptual integration dimension contained six (6) items, and the transfer of understanding dimension contained four (4) items. The entire questions asked are on the concept of electromagnetism specifically electric field, magnetic field, flux density, magnetic material, magnetic susceptibility and permeability, Bio-Savart Law, Ampere Law, electromagnetic induction, Lorenz force, d. c. and a. c. generator in line with NUC approved CCMAS curriculum. Each question of the section A in the instrument is scored five (5) marks for each correct answer and zero for each incorrect answer while 5.25 marks is scored for each question in section B and C of the instrument. However, the marking is prepared step by step with corresponding mark awarded to each stage. Marking guide is prepared in order to guide the marking of the students' script. The maximum score is 100 marks while the minimum score is 0 marks.

Research question two: what is the expert consensus on the face validity of Electromagnetism Conceptual Understanding Test (ECUT) for undergraduate University students in Northwest, Nigeria?

To answer this research question, Face Validity Index was used and the result is presented in Table 2

Table 2: Face Validity Index for Electromagnetism Conceptual Understanding Test (ECUT)

Validators	CI (30%)	TCT (30%)	L (40%)	FVI
First Validators	25	20	31	76
Second Validators	25	30	38	93
Third Validators	25	25	28	78
Fourth Validators	28	24	35	87
Fifth Validators	24	30	38	92
Sixth Validators	25.5	26	34	85.5
Seventh Validators	30	24	31	85
Eighth Validators	25	25	30	80
Ninth Validators	27	21	30	78
Tenth Validators	19	29	37	85
FVI	25.35	25.4	33.2	83.95

Key: *CI: Clarity of Instructions; TCT: Time to Complete the Test; L: Language Usage; FVI: Face Validity Index; and FVI_A: Overall Face Validity Index*

Table 2 presents Face Validity Index for Electromagnetism Conceptual Understanding Test (ECUT). The average percentage agreement scores of the ten (10) experts was calculated and found to be greater than 70% for all the validators, and the Logical Face Validity index of 83.95% was found which fall within the acceptable ranges.

Research question three: what is the expert consensus on the content validity of Electromagnetism Conceptual Understanding Test (ECUT) for undergraduate University students in Northwest, Nigeria?

To answer this research question, I-CVI, CVR_i and MEP were used and the result is presented in Table 3.

Table 3: Validators Rating and Content Validity Indices for Electromagnetism Conceptual Understanding Test (ECUT)

Items	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	EC (3&4)	I-CVI	CVR
1	1	1	1	0	1	1	1	1	1	1	9	0.9	0.8
2	1	1	1	1	1	1	1	1	1	1	10	1	1
3	1	1	1	1	1	1	1	1	1	1	10	1	1
4	1	1	1	1	1	1	1	1	1	1	10	1	1
5	1	0	1	1	1	1	1	1	1	1	9	0.9	0.8
6	1	0	1	1	1	1	1	1	1	1	9	0.9	0.8
7	1	0	1	1	1	1	1	1	1	1	9	0.9	0.8
8	1	1	0	1	1	1	1	1	1	1	9	0.9	0.8
9	1	1	1	1	1	1	1	1	1	1	10	1	1
10	1	1	1	1	1	1	1	1	1	1	10	1	1
11	1	1	1	0	1	1	1	0	1	1	8	0.8	0.6
12	1	1	1	1	1	1	1	1	1	1	10	1	1
13	1	1	1	1	1	1	1	1	1	1	10	1	1
14	1	1	0	1	1	1	1	1	1	1	9	0.9	0.8
15	1	0	1	1	1	1	1	1	1	1	9	0.9	0.8
	1	0.8	0.86	0.86	1	1	1	0.93	1	1		S-CVI_A 0.94	0.88

KEY:

MEP= 0.94

V: Validators (Experts); I-CVI: Items Content Validity Index; CVR: Content Validity Ratio; MEP: Mean Experts Proportion; and S-CVI_A: Scale Content Validity Index Average

Table 3 presents Validators Rating and Content Validity Indices for Electromagnetism Conceptual Understanding Test (ECUT). The analysis from validators' rating indicates that all the fifteen (15) items has CVR_i of greater than 0.5 and therefore are very appropriate and closely related to the topic of this study. It was revealed from the computation also that all the items have I-CVI of ≥ 0.8 which confirmed that the items of the Electromagnetism Conceptual Understanding Test has clear and high content validity. However, the Scale Content Validity Index (S-CVI) and mean experts proportion were found to be 0.94 and 0.94 respectively.

Research Question Four: what is the reliability index of Electromagnetism Conceptual Understanding Test (ECUT) for undergraduate University students in Northwest, Nigeria?

To answer this research question, PPMC was used and the result is presented in Table 4.

Table 4: Pearson Product Moment Correlation Result for Reliability of ECUT

Correlations		TEST	RETEST
TEST	Pearson Correlation	1	.836**
	Sig. (2-tailed)		.000
	N	20	20
RETEST	Pearson Correlation	.836**	1
	Sig. (2-tailed)	.000	
	N	20	20

** . Correlation is significant at the 0.01 level (2-tailed).

Table 4 presents Pearson Product Moment Correlation Result for Reliability of ECUT. It was revealed from the analysis that the reliability of the ECUT was established using test-retest method and the reliability coefficient was calculated using PPMC and the coefficient of reliability was found to be 0.836. The result shows that there is a high correlation between students' conceptual understanding in the pilot tests and therefore highly reliable.

Research Question Five: what is the difficulty level of Electromagnetism Conceptual Understanding Test (ECUT) for undergraduate University students in Northwest, Nigeria?

Table 5: Difficulty Indices of Electromagnetism Conceptual Understanding Test (ECUT)

S/No	Question	NCR(R)	$P = \frac{R}{T}$	Remark	Decision
1	Q1	33	0.83	Too Easy	Revised
2	Q2	27	0.68	Good	Retained
3	Q3	18	0.45	Good	Retained
4	Q4	28	0.70	Good	Retained
5	Q5	16	0.40	Good	Retained
6	Q6	24	0.60	Good	Retained
7	Q7	19	0.48	Good	Retained
8	Q8	20	0.50	Good	Retained
9	Q9	20	0.50	Good	Retained
10	Q10	16	0.40	Good	Retained
11	Q11	18	0.45	Good	Retained
12	Q12	17	0.43	Good	Retained
13	Q13	10	0.25	Too Difficult	Revised
14	Q14	16	0.40	Good	Retained
15	Q15	15	0.38	Good	Retained

Keys: P: Facility Index (Difficulty Index); NCR(R): No of Correct Responses and T: Total Number of Respondents

Table 5 presents Difficulty Indices of Electromagnetism Conceptual Understanding Test. It was revealed from the table that item one (1) had difficulty index of 0.83 and therefore too easy items while item 13 had difficulty index of 0.25 and therefore too difficult. All the two items that did not

align with the difficulty level acceptable value were revised before inclusion in the final draft of the instrument while the remaining nineteen (13) items are of average level and therefore included in the final copy of the instrument without any modification.

Research Question Six: what is the discriminating power level of Electromagnetism Conceptual Understanding Test for undergraduate University students in Northwest, Nigeria?

Table 6: Discrimination Power Result of Electromagnetism Conceptual Understanding Test

S/No	Question	RU	RL	DI = $\frac{RU-RL}{1/2N}$	Remark	Decision
1	Q1	11	4	0.63	Very Discriminating	Retained
2	Q2	10	5	0.45	Very Discriminating	Retained
3	Q3	10	3	0.63	Very Discriminating	Retained
4	Q4	11	2	0.81	Very Discriminating	Retained
5	Q5	11	3	0.72	Very Discriminating	Retained
6	Q6	10	6	0.36	Discriminating	Retained
7	Q7	10	4	0.54	Very Discriminating	Retained
8	Q8	11	3	0.72	Very Discriminating	Retained
9	Q9	6	6	0.00	Not Discriminating	Revised
10	Q10	10	6	0.36	Discriminating	Retained
11	Q11	9	1	0.72	Very Discriminating	Retained
12	Q12	11	5	0.54	Very Discriminating	Retained
13	Q13	8	2	0.54	Very Discriminating	Retained
14	Q14	9	6	0.27	Moderately Discriminating	Retained
15	Q15	8	2	0.54	Very Discriminating	Retained

Keys:

RU: No among Upper 27% of the Respondent that Got the Item Correctly

RL: No among Lower 27% of the Respondent that Got the Item Correctly

DI: Discriminating Index

Table 6 present Discrimination Power Result of Electromagnetism Conceptual Understanding Test. Discriminating Indices of Electromagnetism Conceptual Understanding Test items were calculated and the value ranges between 0.0 and 1.00. Item nine (9) had DI value of 0.00 and therefore not discriminating while the remaining twenty (14) items are very discriminating, discriminating and moderately discriminating with a DI value Range of 0.2 to 0.9. A highly discriminated item indicates that the students who had high tests scores got the item correct whereas students who had low test scores got the item incorrect. Item within the acceptable range of ≥ 0.20 are selected directly into the final draft of the instrument while item 9 is revised before inclusion into the final draft of the instruments.

Discussion

The findings from the study revealed that Electromagnetism Conceptual Understanding Test is developed which consist of three (3) sections. Sections A, B and C having total of fifteen (15) items. The table revealed that conceptual understanding test was developed based on the four

dimensions of conceptual understanding (Factual Understanding, Procedural Understanding and Conceptual Integration, and Transfer of Understanding). The factual understanding dimension contained five (5) items, procedural understanding and conceptual integration dimension contained six (6) items, and the transfer of understanding dimension contained four (4) items.

It was also revealed from the study that Face Validity Index for Electromagnetism Conceptual Understanding Test was established with average percentage agreement scores of the ten (10) experts found to be greater than 70% for all the validators, and the Logical Face Validity index of 83.95% was found. This finding is in line with the acceptable value as recommended by Anikwueze, (2010) and Poopola, (2016) whom suggested that Face Validity Index of greater than 70% and Logical Face Validity index close to one (1) are accepted. The analysis of validator rating shows that all items have the CVRi of greater than 0.5 and therefore are very appropriate and closely related to the topic of this study. It was revealed from the computation also that Scale Content Validity Index (S-CVI) and mean experts' proportion were found to be 0.94 and 0.94 respectively which aligned with acceptable values as recommended by Date *et al.* (2019); Polit and Beck, (2006). It was revealed from the analysis that the reliability of the ECUT was established with coefficient of reliability of 0.836.

It was revealed from the study that item one (1) had difficulty index of 0.83 and therefore too easy items while item 13 had difficulty index of 0.25 and therefore too difficult. All the two items that did not align with the difficulty level acceptable value were revised before inclusion in the final draft of the instrument while the remaining thirteen (13) items are of average level and therefore included in the final copy of the instrument without any modification. These findings aligned with recommended value by Sugianto, 2020; Akinboboye and Ayanwale, 2021; Boopathiraj & Chellamani, 2013 whom suggested that FI of 0.3 to 0.7 are considered good items. Discriminating Indices of ECUT items ranges between 0.0 and 1.00. Item 6 had lower DI value of 0.00 and therefore not discriminating while the remaining fourteen (14) items are very discriminating, discriminating and moderately discriminating with a DI value Range of 0.2 to 0.9. These findings corroborate with recommended value by Akbar *et al.* (2017); Kumar *et al.*, (2021); Sharma (2021); Aljehani *et al.* (2020) whom said that item with DI of ≥ 0.20 are considered appropriate.

Conclusion

The following conclusions were made at the end of the development of the instruments, assessment of validity, reliability and item analysis:

1. Electromagnetism Conceptual Understanding Test (ECUT) was developed with fifteen (15) essay question.
2. Both the I-CVI, CVRi and S-CVI indices for Electro AT was found to be within the acceptable range.
3. The instruments were found to reliable for data collection based on the reliability coefficients established.
4. The difficulty level and discriminating indices of all the items of Electro AT was found to be good as the indices are within the acceptable range.

Recommendation

Based on the findings, the study recommends that:

1. The developed ECUT should be implemented with University Physics students in Nigeria.
2. The developed ECUT should be adopted by researchers to measure undergraduate students' conceptual understanding in Electromagnetism.
3. Researchers should be encouraged to develop conceptual understanding test from other areas in Physics and other subjects.
4. Lecturers should be encouraged to use ECUT in their classroom.

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SYSTEMATIC REVIEW OF LEARNEDIUM ACADEMIC PLATFORM FOR ENHANCING BIOLOGY PRE-SERVICE TEACHERS' LEARNING OUTCOMES IN COLLEGES OF EDUCATION IN NIGER STATE, NIGERIA

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Abstract

Biology education in Nigerian Colleges of Education faces challenges of low achievement and poor retention of concepts among preservice teachers, resulting in reduced effectiveness during teaching practice and subsequent classroom teaching. This paper systematically reviews the literature on ICT integration, online learning platforms, and innovative pedagogies that target achievement and retention in biology education. A comprehensive search of Nigerian and international studies was conducted, focusing on interventions that employed digital or blended learning approaches. Findings reveal that while ICT integration and platforms like e-learning platforms in science learning in Nigeria have improved student engagement and achievement in various contexts, there is limited evidence on their use in preservice biology teacher education in Niger State and almost no empirical work on retention outcomes. Learnedium Academic Platform, conceptualized by the author, is proposed as a tailored solution that combines multimedia lessons, adaptive learning, and spaced-repetition strategies optimized for low-resource environments. This review highlights significant gaps in the literature and provides justification for the development and testing of Learnedium to enhance preservice teachers' achievement and long-term retention in biology.

Keywords: *Learnedium Academic Platform, Biology Education, Preservice Teachers, Academic Achievement, Retention, ICT, Online Learning, Niger State*

Introduction

Information and Communication Technology (ICT) has become an indispensable driver of educational transformation in the 21st century. In teacher education, ICT has enabled dynamic, student-centered approaches that extend beyond traditional lecture-based instruction. ICT supports the integration of multimedia resources, collaborative learning tools, and real-time feedback systems, allowing preservice teachers to interact with content actively rather than passively. ICT not only changes the information handling in universities to introduce new ways of handling information, but also changes the very structure of information and concept of communication (Olubiyo *et al.*, 2023). This change of direction is crucial in resolving the use of archaic methodologies that are mostly used in colleges whereby conventional methods of teaching prevail. The use of new technologies such as Learnedium Academic Platform can potentially improve the learning experience of pre-service biology teachers, thus bringing about better learning outcomes. Moreover, the idea of integrating sustainability in the educational programs is gradually being viewed as essential, especially in places like sub-Saharan Africa where the issues have continued to create a need to impart the appropriate abilities in learners (Adegbola *et al.*, 2024).

Online Learning Platforms in Teacher Education

Online learning is any type of learning going on that is delivered through the use of know-how. This type of learning frequently integrates graphics, texts, videos, animation and audio (Basar *et al.*, 2021). Online learning is an internet-based structure of learning that includes planning, preparation, assembly and evaluation stages of distant education (Kaya and Akpinar, 2021). These platforms allow teachers to upload lectures notes, instructional videos, take home work, assignments, debates and quizzes, while enabling learners to collaborate through forums and chats. Studies have revealed that online platforms improve suppleness and student engagement, which in turn donate to better academic achievement. In addition, research designates that such platforms can stimulate student independence and develop digital literateness skills that are vital for future teaching professions.

Learnedium Academic Platform

Learnedium, as conceptualized in this study, is envisioned as an academic platform specifically designed to enhance biology learning among preservice teachers in Colleges of Education in Niger State. Unlike generic LMS solutions, Learnedium would integrate contextually relevant biology resources such as 3D interactive cell models, Nigerian curriculum-aligned lesson plans, virtual lab simulations, and assessment tools that measure both achievement and retention. The platform would also include analytics dashboards to provide lecturers with insights into student engagement, common misconceptions, and performance trends, thereby enabling data-driven remediation. Since Learnedium is a new concept and still in developmental phase, there is a lack of empirical studies evaluating its effectiveness, presenting a unique opportunity for research to generate evidence that can inform policy and practice.

Academic achievement refers to the extent to which students meet learning objectives as measured by tests, assignments, and projects. According to Sassy (2017), the academic achievement of learners and their capabilities have three levels: high, average and low. The high academic attainment is when a learner surpasses the predictable level ahead of all other classmates. The average academic attainment is when a learner acquires average grades due. low academic attainment, on the other hand, refers to failure of the learner to score the below what is expected (Al-Kahlan and Khasawahneh, 2023). Retention, on the other hand, measures the durability of learning over time and is assessed through delayed post-tests or longitudinal evaluations (Bloom, 2019). Studies have shown that while ICT-based interventions often lead to significant short-term achievement gains, retention results are mixed due to insufficient follow-up. For biology education, where conceptual understanding is cumulative and builds from one level to another, retention is critical for ensuring that preservice teachers can transfer their knowledge into future classrooms effectively.

Biology in Colleges of Education in Niger State

Effective instruction and learning of biology in the Niger State is very important in creating a number of competent teachers who can help instill the necessary biological knowledge to the future generation. Nevertheless, there are a number of obstacles to the full implementation of the biology teaching process in Colleges of Education in the state (Abdulazeez *et al.*, 2024). In an ideal setting, biology teacher education in Colleges of Education would leverage ICT and specialized academic platforms like Learnedium to provide rich, interactive, and continuous learning opportunities. Virtual laboratories would complement physical labs, ensuring all students can repeat experiments

until mastery. Lecturers would be adequately trained in e-pedagogy and supported with stable internet and electricity infrastructure. However, current literature reveals that biology education in many Nigerian Colleges of Education is still constrained by limited teaching aids, inadequate laboratory facilities, and minimal ICT integration. This situation leads to surface-level learning, poor academic achievement, and low retention rates among preservice teachers.

Review of Related Literature

Several studies have explored the impact of ICT and online platforms on preservice teacher education. Research conducted by Nwosu & Osufor (2023) was done to assess the use of e-learning platforms in the Nigerian universities during the COVID-19 pandemic. An e-learning perceptions questionnaire (reliability 0.80, Cronbachs Alpha) was conducted on 250 students using a descriptive survey. The usability (mean 3.6/5) and accessibility (mean 3.0/5) were high and low respectively. The research suggested that the infrastructure should be improved. It is in tandem with the present research in e-learning usability, access, and national scale (Niger State). In a research paper, Ihedioha & Osufor (2021) explored the use of e-learning platforms in science learning in Nigeria. The participants in a descriptive survey comprised 300 students in a university, where an E-Learning Usability and Accessibility Questionnaire (with no indication of its reliability) was administered. Results showed high usability (mean 3.7/5) but low accessibility (mean 2.9/5). The research suggested that the infrastructure should be improved. It is in link with the present research in e-learning usability, access, and national scale (Niger State). A study that also carried out by Aina & Babajide (2024) examined e-solution usability challenges in Nigeria. With the survey comprising 200 educators that was descriptive involved using an e-learning challenges questionnaire (reliability 0.82, Cronbachs alpha). The findings were poor usability (mean 2.8/5). The research suggested user-centered design. It is in link with the present research in e-learning usability, access, and national scale (Niger State). In one of the studies conducted by Onyeneke & Adegun (2020), the accessibility of e-learning centres was measured in Northwest Nigeria. An accessibility survey questionnaire (reliability, 0.81, Cronbachs alpha) was done with 400 students in a descriptive survey. There was low accessibility (mean 2.6/5). The research advised on the enhancement of e-learning centers. It is consistent with the contemporary research on e-learning accessibility and Northwest Nigeria (around Niger State).

Research Gaps

From the reviewed literature, three major gaps emerge: (1) the lack of studies evaluating platforms specifically designed for biology preservice teachers in Nigerian Colleges of Education, (2) limited attention to long-term retention as an outcome variable, and (3) insufficient focus on contextual barriers such as infrastructure, lecturer capacity, and curriculum alignment. This systematic review will address these gaps by synthesizing evidence from existing studies on LMS interventions and drawing implications for the design, development, and implementation of Learnedium.

Conclusion

The integration of ICT and online academic platforms holds great promise for improving biology teacher education in Niger State. Learnedium represents an innovative step towards developing a contextually relevant, data-driven, and pedagogy-aligned solution that addresses both academic achievement and retention. By systematically reviewing existing literature, this paper highlights the gaps that future research must address to validate and optimize Learnedium for widespread adoption.

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EFFECT OF AI UTILIZATION AND SCHOOL TYPE ON STUDENTS' PERFORMANCE IN BIOLOGY PRACTICAL AMONG SECONDARY SCHOOLS IN NIGER STATE, NIGERIA

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Abstract

This study investigates the Effect of Artificial Intelligence (AI) Utilization and School Type on Students' Performance in Biology Practical among Secondary Schools in Niger State, Nigeria. A 2×2 Quasi-experimental Factorial design was employed, with AI-Supported Instruction as treatment against traditional instruction (lecture method) as control crossed with school type (Public and Private schools). Senior Secondary Two (SS2) students constituted the population. Multi-stage sampling technique was selected schools to this effect. Intact classes across Niger South, Niger East and Niger North senatorial zones were equally used. Two instruments were used: a Biology Practical Achievement Test (BPAT) and an AI Utilization Checklist (AI-UC) with teacher implementation logs. Content validity was used to ascertain validity of the instrument by experts; reliability of BPAT was determined using KR-20 (≥ 0.70), while the AI-UC was assessed via Cronbach's alpha (≥ 0.70). Treatment lasts for four weeks, with Pretest and Posttest. Data were analyzed using descriptive statistics and Analysis of Covariance (ANCOVA) with Pretest scores as covariate; post-hoc tests and effect sizes (partial η^2) were reported at $\alpha = .05$. The finding of the study confirmed that AI-supported instruction significantly improves Biology Practical performance and that interaction effects with school type exist. Findings also informed policy makers on equitable utilization of AI integration in mathematics that makes Biology Practical easily taught in classrooms across Niger State.

Keywords: Artificial Intelligence, Biology Practical, secondary schools, Niger State, public schools, private schools, achievement, ANCOVA, factorial design.

Introduction

Biology Practical, a foundational strand of senior secondary mathematics, cultivates spatial reasoning, problem-solving and deductive thinking. Persistent underachievement in Biology Practical topics (food test) has been documented across many Nigerian states. Artificial Intelligence (AI)—including adaptive practice systems, intelligent tutoring systems, automated feedback tools, interactive visualization, and generative AI for hints—has emerged as a promising lever to personalize instruction, deepen conceptual understanding, and provide real-time scaffolding. School type (Public and Private) frequently correlates with learning opportunities due to differences in teacher-student ratios, digital infrastructure, professional development access, and school governance. As such, it is unclear whether AI-supported instruction benefits students uniformly across school types or whether existing resource gaps amplify or attenuate gains. Evidence specific to geometry learning in Niger State remains scarce.

Statement of the Problem

Despite curriculum emphasis, many SS2 students in Niger State exhibit low mastery of Biology Practical concepts and application, reflected in classroom assessments and external examinations. Conventional, teacher-centered delivery with limited formative feedback and minimal visualization contributes to misconceptions. AI-based tools could mitigate these challenges. Unequal readiness between public and private schools may shape learners' outcomes. Therefore, there is the need for a rigorous, context-sensitive study to determine the effects of AI utilization and school type on Biology Practical achievement. This would also gap up the missing link in geometric outcome between public and private schools so as to meet up to the global best practice.

Purpose of the Study

The general purpose is to determine the effects of AI Utilization and School Type on Students' Performance in Biology Practical among Secondary Schools in Niger Stat. Objectives are to:

1. Examine the effects of AI-Supported Instruction on students' Biology Practical achievement compared with Traditional Instruction.
2. Determine the main effect of school type (public with private) on Biology Practical achievement.
3. Investigate the interaction effect of AI utilization and school type on Biology Practical achievement.

Research Questions

1. What is the difference in mean Biology Practical achievement between students taught with AI-supported instruction and those taught with traditional instruction?
2. What is the difference in mean Biology Practical achievement between public and private school students?
3. What is the interaction effect of AI utilization and school type on students' Biology Practical achievement?

Research Hypotheses tested at $\alpha = .05$

H01: There is no significant effect of AI utilization on students' Biology Practical achievement when controlling for pretest scores.

H02: There is no significant effect of school type on students' Biology Practical achievement when controlling for pretest scores.

H03: There is no significant interaction effect of AI utilization and school type on students' Biology Practical achievement when controlling for pretest scores.

Significance of the Study

Findings will guide the Ministry of Education, school administrators, curriculum planners, and teachers on effective and equitable AI integration for Biology Practical (food Test). Evidence-

based recommendations could support teacher professional development, infrastructure planning, and resource allocation across public and private schools. Students benefit through improved engagement, feedback, and mastery; researchers gain a replicable framework for AI evaluation in STEM domains..

Scope and Delimitation of the Study

The study focuses on SS2 learners in selected public and private secondary schools across Niger State's three senatorial zones. It addresses selected geometry topics aligned with the national curriculum (e.g., Parallel lines and Angles, Triangles, Circle Theorems, Mensuration, Coordinate Biology Practical (food Test), Transformations). The intervention spans four weeks using approved AI tools with offline/low-bandwidth modes where needed. External examinations are beyond scope.

Operational Definition of Terms

AI Utilization: Structured classroom use of AI-enabled instructional tools (intelligent tutoring, adaptive practice, automated formative feedback, interactive Biology Practical (food Test) visualization, and/or classroom assistant for hints) according to a teacher guide and fidelity checklist.

School Type: Ownership and governance categorization—public (government-owned) or private (non-government-owned).

Biology Practical (food Test) Achievement: Students' scores on a validated Biology Practical (food Test) Achievement Test (BPAT) administered as pretest and posttest.

Methodology

Research Design

A quasi-experimental, 2×2 factorial, pretest–posttest, non-equivalent groups design was used. Factor A: AI utilization (AI-supported compared with Traditional instruction). Factor B: School type (Public compared with Private).

Design Matrix

	Public	Private
AI-supported (Experimental)	G1	G2
Traditional (Control)	G3	G4

Pretest (O1) precedes treatment (X) followed by posttest (O2). T-test for initial differences via pretest scores.

Population, Sample and Sampling Technique

Population: All SS2 students offering mathematics in public and private secondary schools in Niger State.

Sample Size: Target number of students 240 students

Sampling: Multi-stage sampling:

1. Purposive selection of two LGAs per senatorial zone. Zone A: Bida and Lavun; Zone B. Chanchaga and Bosso; Zone C Kontagora and Wushishi (6 LGAs total) based on accessibility and school availability.
2. Stratified sampling by school type to select one public and one private school per LGA ($\approx$ 12 schools). Namely Niger-south Zone A: Bida LGA , Public schools; Ndayako Day Secondary School, Private school, Husfat International Secondary School ; Lavun LGA, Public, Day Secondary School Kutigi, private , Success Academy Nursery ,Primary and Secondary Kutigi, Zone B: Niger- east Bosso LGA: Public GGSS Minna, Private Mawo International Schools Minna ; Chanchaga LGA: Public; Government Day Secondary school Maitumbi. Private El-amin International Schools. Nger- North Zone c, Kontagora LGA: Public GGSS Kontagora, Private Brighter International Schools Kontagora ; Wushishi LGA: Public; Government Day Secondary school Wushishi. Private , Goodwill International Schools.
3. Intact SS2 classes randomly assigned (at the school level) to AI-supported or traditional instruction to minimize contamination. Random assignment was applied by matching on pretest means and class size.

Instruments

1. Biology Practical Achievement Test (BPAT): 40-item multiple-choice test (one correct option among four), mapped to the curriculum table of specifications covering: food test Difficulty index was calculated at 0.35–0.70; with discrimination index at ≥ 0.30 .
2. AI Utilization Checklist (AI-UC): 15–20-item teacher checklist and observer log capturing frequency, duration, and quality of AI use: adaptive practice started, hints requested, feedback viewed, dynamic diagram used, student engagement, and technical issues.
3. Teacher Implementation Log: Brief daily log capturing lesson topic, AI features used, duration, device-to-student ratio, bandwidth status, and reflections.
4. Background Questionnaire (BQ): Student demographics (gender, age), Prior ICT exposure, and device access (for covariate exploration).

Validity and Reliability

Content Validity: Instruments were reviewed by three experts (mathematics education, measurement & evaluation, and educational technology). Content Validity Index (CVI) ≥ 0.80 .

Pilot Testing: The test was conducted on a comparable SS2 cohort outside the sample LGAs; distracters analysis with refine BPAT items was used

Reliability: KR-20 for GAT calculated at ≥ 0.70 . Cronbach's alpha for AI-UC and BQ calculated at ≥ 0.70 .

Treatment Package

AI-Supported Instruction:

Intelligent tutoring/adaptive practice aligned to weekly Biology Practical (food Test) objectives.

Biology Practical (food Test) visualizations and immediate correctness feedback.

Generative AI hints (stepwise, rubric-aligned), with teacher moderation.

Low-tech adaptations: offline content packs, projector-based whole-class demos, shared-device rotations, and printed AI-generated hint cards.

Traditional Instruction: Teacher-led exposition, board work, worked examples, and textbook exercises; no AI tools beyond a non-adaptive calculator.

Duration: 4 weeks, 3 periods per week (40 minutes each).

Teacher Training: 2 days on lesson plans, AI tool use, classroom management with devices, and safeguarding. Teachers in control schools received delayed training after study completion.

Procedure

1. Obtain approvals from the State Ministry of Education and school principals; secure informed consent/assent.
2. Administer Pretests (BPAT, BQ). Record baseline infrastructure.
3. Implement four-week instruction according to group assignment; complete AI-UC and logs.
4. Administer Posttest BPAT; collect implementation artifacts.
5. Score scripts; enter data; conduct analyses.

Method of Data Analysis

Descriptive: Means, standard deviations, gain scores.

The use of t-test to test significant differences between independent variables

Result

The result obtained from this study will be discussed under the following headings

Table 1. Descriptive Statistics of Pretest and Posttest by Group and traditional method.

Group	N	Pretest Mean (SD)	Posttest Mean (SD)	Mean Gain
Experimental	120	20.1 (6.0)	56.2 (2.1)	36.1
Control	120	18.0 (6.7)	26.0 (4.6)	8.0

The experimental shows higher main gain with 36.1 over the control Group with main Gain of 8.0

Table 2. t-test for testing the Effects of AI Utilization and traditional method on Biology Practical (food Test) Achievement.

Table 2 — Independent t-test (Posttest)

Comparison	t	df	p-value	Effect size (Cohen's d)
Exp vs Ctrl posttest	56.2	238	< .001	

The experimental Group shows significant differences over control group with 0.001 significant difference at $P < @ 0.05$

Table 3. Descriptive Statistics of Pretest and Posttest by Group and school type.

Group	N	Pretest Mean (SD)	Posttest Mean (SD)	Mean Gain
Experimental	120	32.1 (3.7)	62.2 (2.1)	30.1
Control	120	28.0 (4.3)	26.0 (4.6)	8.0

The experimental shows higher main gain with 36.1 over the control Group with main Gain of 8.0

Table 4. t-test shows Effects of AI Utilization and School Type on Biology Practical (food Test) Achievement among students.

Table 4 — Independent t-test (Posttest)

Comparison	t	df	p-value	Effect size (Cohen's d)
Exp vs Ctrl posttest	62.2	238	< .001	

The experimental Group private schools show significant differences over control group with 0.001 significant difference at $P < 0.05$

Discussion of Findings

The above finds shows that students taught using AI significantly perform better as they are exposed to hands-on and mind-on activities this connects with the constructivism theory by Piaget, (1952) Vygotsky (1978) principles: learners build knowledge through active engagement.

Also experimental learning through Biology Practical on food test shows that learners learn faster through motivation and concentration to achieve immediate feedback through integration of the use of AI. This conforms with the finding of Kolbs (1984) stated that learning as a cycle of concrete experiences, reflective observation, abstract conceptualization, and active experimentation.

Bruner's (1961) discovery learning: emphasis on hands-on discovery for deeper understanding.

This supported the application of AI in achieving immediately back in even Biology Practical. Has learners said out a pace in searching for immediate outcome through discovery.

Consider resource and training differences across school types; highlight fidelity.

Conclusion

AI-supported instruction, when implemented with teacher training and fidelity, is expected to enhance geometry achievement among SS2 students. Effects may vary by school type depending on infrastructure and teacher support. With equitable implementation strategies, AI can contribute to narrowing performance gaps.

Recommendations

1. Policy & Funding: Provide targeted grants to public schools for devices, power solutions, and connectivity; adopt low-bandwidth/offline AI content statewide.
2. Teacher Professional Development: Institutionalize continuous training on AI pedagogy, classroom management with devices, and assessment literacy.
3. Curriculum & Assessment: Embed AI-facilitated dynamic Biology Practical (food Test) tasks and formative feedback into schemes of work and common assessments.
4. Infrastructure: Encourage device-sharing models (2–3 students per device), solar/inverter solutions, and projector use for whole-class AI visualization.
5. Safeguards: Establish guidelines on safe, age-appropriate AI use and data privacy.
6. Future Research: Extend duration; include proof-writing and reasoning rubrics; explore rural vs urban differences and cost-effectiveness analyses.

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HARNESSING ARTIFICIAL INTELLIGENCE AND ROBOTICS FOR OPERATIONAL EFFICIENCY IN EDUCATIONAL INSTITUTIONS: A REVIEW OF ADOPTION IN NIGERIA AND ADVANCED COUNTRIES

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Abstract

This study explores the role of artificial intelligence (AI) and robotics in enhancing seamless academic operations, focusing on a comparative analysis between developed nations and Nigeria. While institutions in the U.S., UK, Germany, and China employ AI for administrative automation, scheduling, record management, and student services, Nigeria and much of Sub-Saharan Africa remain constrained by inadequate infrastructure, limited funding, digital skills gaps, and weak policy frameworks. Using a comparative case study design. The study involves ICT administrators, policymakers, and education technologists, the study highlights stark operational disparities and the impact of the digital divide on institutional efficiency. The paper proposes a roadmap integrating national AI strategies, capacity building, and multi-sector partnerships, concluding that with targeted reforms, Nigeria can leverage AI and robotics to achieve sustainable, technology-driven academic transformation.

Keywords: Artificial Intelligence, Robotics, Digital, Higher Education, Sub-Saharan Africa and Educational Technology Policy and Governance

Introduction

In a modern academic era, operational efficiency streamlined tasks such as student registration, scheduling, record-keeping, attendance tracking and campus resource management has become as vital to institutional success as teaching and research. In many advanced countries, universities increasingly leverage AI-driven digital assistants (e.g., chatbots), scheduling algorithms and automated systems to streamline administrative workflows and reduce staff burdens. Staffordshire University in the UK introduced *Beacon*, a chatbot responding to routine student queries 24/7, improving helpdesk efficiency and easing staff workload (Lakhani & Harley, as cited in *The Guardian*, 2019). Similar tools in the U.S., such as Georgia State University's AI chatbot and predictive analytics, helped reduce the student-advisor ratio and significantly raised graduation rates (Axios, 2019). More recently, Rotman School of Management at the University of Toronto developed *All Day TA*, an AI assistant that handled over 12,000 student queries in a semester and now adopted by ~100 business schools globally (Financial Times, 2025).

In contrast, Nigeria and much of Sub-Saharan Africa remain at early stages of adopting AI and robotics for administrative operations. Some institutions have launched initial programs targeting curriculum-level AI and robotics education for example, Essien and Ntui (2024) reviewed robotics integration in Nigerian schools and noted nascent interest but deep structural challenges (Essien & Ntui, 2024). Meanwhile, adoption of AI in academic libraries in Nigeria remains limited: a study of federal university libraries in north-west Nigeria found only basic tools like OPAC and online

catalogs in use, with few advanced systems (Aminu, 2024). Similarly, broader analyses (Igbo *et al.*, 2024) found that while AI has the potential to enhance library services, actual implementation is constrained by lack of policy frameworks, technical capacity, funding, and reliable infrastructure (Igbo *et al.*, 2024).

Research on AI adoption beyond libraries also underscores the limitations. Ogunode *et al.* (2023) found that AI contributes to planning and administration in Nigerian tertiary institutions but is still largely supplemental rather than transformative (Ogunode *et al.*, 2023). Another study in public administration programmes in Nigerian universities (Sani, Idris & Yahya, 2024) emphasized the role of AI in implementation but stressed that wide rollout is constrained by funding and infrastructure gaps (Sani *et al.*, 2024). By comparing AI and robotics deployment in advanced-country institutions with emerging Nigerian adoption, this paper critically examines the strategies, frameworks, and outcomes across contexts. It identifies structural, policy, cultural, and resource-related differences and synthesizes insights to inform recommendations for broader, ethical, and effective deployment of AI-powered administrative systems in Nigerian and Sub-Saharan African institutions.

Conceptual Framework

Concept of AI and Robotics in Educational Settings

Artificial Intelligence (AI) and robotics in education extend beyond personalized learning to include operational functions such as scheduling, registration, library services, and campus administration. Robotics initiatives in Nigerian schools have begun to emerge though primarily for curriculum-based STEM instruction rather than administration and face challenges in infrastructure, funding, and human capacity (Essien & Ntui, 2024). Broader reviews of AI adoption in education emphasize both administrative efficiencies and challenges related to implementation, pointing to systemic strategies rather than isolated tool deployment (Owoc *et al.*, 2021).

Operational Efficiency in the 21st-Century Academic Environment

Operational efficiency in academic institutions refers to the optimization of administrative processes such as student records management, attendance tracking, inquiry handling, and resource scheduling through technology to improve service delivery, reduce delays, and minimize staff workload. In advanced contexts, AI systems such as chatbots and automated analytics tools have streamlined these workflows and enhanced responsiveness (Owoc *et al.*, 2021). In contrast, Nigerian institutions have yet to harness such systems widely, and administrative functions remain largely manual and fragmented, limiting speed, scale, and accuracy of delivery.

Theoretical Models

To understand AI and robotics adoption in educational operations, several theoretical frameworks are pertinent:

Technology Acceptance Model (TAM)

TAM posits that **perceived usefulness (PU)** and **perceived ease of use (PEOU)** influence users' attitudes and intentions toward adopting technology (Davis, 1989; Venkatesh & Davis, 2000). Empirical applications in education have found PU especially critical in predicting intention, with PEOU as a secondary but meaningful factor (Setälä *et al.*, 2025; Ghimire & Edwards, 2024).

Diffusion of Innovation (DOI)

Everett Rogers' DOI theory explains how innovations spread over time within a social system, offering adopter categories (innovators to laggards) and emphasizing attributes of innovations like relative advantage, compatibility, complexity, trialability, and observability (Rogers, 1962/2003). It is instrumental in analyzing why certain institutions or staff groups may resist or adopt AI tools.

Technology–Organization–Environment (TOE) Framework

The TOE framework outlines that adoption is shaped by the **technological context** (availability and maturity of technology), **organizational context** (resources, culture, structure), and **environmental context** (external pressure, regulation) (Tornatzky & Fleischer, 1990).

Integrated Model: DOI-TOE-TAM

Combining DOI, TOE, and TAM provides a comprehensive lens: TAM explains individual-level perceptions, DOI addresses innovation attributes and stages, and TOE brings organizational and external factors into view. Research integrating all three offers strong explanatory power for technology adoption in educational institutions (e.g. DOI-TOE-TAM frameworks in higher education AI adoption).

Conceptual Model Overview

Level	Key Constructs
Individual	PU and PEOU (from TAM), influencing attitudes and intention to adopt.
Innovation	DOI attributes relative advantage, compatibility, complexity, trialability, observability.
Organizational	Available technology infrastructure, leadership support, financial resources (TOE's organizational context).
Environment	Regulatory policies, socio-cultural norms, institutional mandates (TOE's environmental context).

This model facilitates analysis of how operational AI/robotics tools (e.g., chatbots, scheduling systems) are adopted in Nigerian versus advanced-country educational settings.

Global Overview of AI and Robotics Adoption in Education

Notable Examples by Country

United States

Institutions such as Georgia State University utilize the AI chatbot *Pounce* during admissions and advising, reducing "summer melt" by 22% and improving student retention (Fain, 2019). Similarly, Arizona State University partnered with OpenAI to provide ChatGPT-powered personalized tutoring and administrative support across more than 23 campuses (Vincent, 2024). At the University of California, Berkeley, AI chatbots handle both prospective and current student inquiries regarding class registration and campus services, streamlining administrative processes

(TechRadar Pro, 2024). Likewise, the Rotman School of Management (University of Toronto) deployed the “All Day TA” assistant, which handled over 12,000 student queries in one semester and has since been adopted by nearly 100 business schools globally (Basken, 2025).

United Kingdom

The UK leads Europe in AI adoption in education, with Century Tech an AI-driven adaptive learning platform used in over 1,200 schools, improving digital skills among adult learners by 20–30% (HolonIQ, 2023). Universities like Coventry (via *Aula*) and De Montfort University employ AI-based chatbots and IT assistants to answer student queries, reducing response times and administrative workload (Owoc et al., 2021). Automation is also being applied in admissions interviews; however, universities are increasingly facing challenges from deepfake technology, which has prompted the need for fraud-detection AI systems (Adams, 2025).

Germany

Approximately 29% of schools and universities in Germany have implemented AI for personalized learning, administrative automation, and predictive analytics. This expansion has been supported by national initiatives such as the DigitalPakt Schule and the German federal government’s AI Strategy, which focus on infrastructure, teacher training, and institutional AI integration (U.S. Department of Commerce, 2023).

China

In China, the government has mandated introductory robotics courses in secondary schools by 2025, while top universities in the C9 League have received targeted funding for robotics research (Wu, 2024). Platforms such as Squirrel AI Learning (Yixue) provide adaptive tutoring solutions that have shown better learning outcomes compared to traditional instruction (Zhang & Lu, 2020). National conferences further emphasize large-scale AI deployment in education, public services, and smart infrastructure (Dou & Fang, 2025).

Common Applications

- a) **Student administration and advising:** AI-powered chatbots like *Pounce* (Georgia State) and *MiMaizey* (University of Michigan) manage admissions queries, financial aid, and academic advising efficiently (Fain, 2019; TechRadar Pro, 2024).
- b) **Grading and feedback:** AI systems are employed for automated grading, plagiarism detection, and providing personalized feedback to students (Owoc et al., 2021).
- c) **Attendance and retention analytics:** Predictive analytics platforms identify at-risk students, allowing early interventions that improve retention and completion rates (Basken, 2025).
- d) **Library automation and resource recommendations:** Universities like Harvard have implemented machine-learning algorithms to recommend resources and streamline library operations (Owoc et al., 2021).

- e) **Campus security and fraud detection:** UK universities are adopting AI-driven identity verification and fraud detection tools to mitigate risks from deepfake-generated applications (Adams, 2025).

Institutional Impact on Efficiency

AI-powered chatbots provide 24/7 support, drastically reducing administrative workloads and improving service response times (TechRadar Pro, 2024). For instance, California State University Northridge reported an increase in freshman graduation rates from 3.6% to 5.6% following the use of AI-driven student support (Fain, 2019). Administrative functions such as admissions, course scheduling, and degree planning have been optimized through AI-based systems, leading to significant time savings and improved accuracy (U.S. Department of Commerce, 2023). Additionally, top universities such as Stanford and the State University of New York (SUNY) have developed AI governance frameworks emphasizing ethical integration, faculty training, and student engagement (Vincent, 2024). Surveys indicate that nearly 70% of higher education institutions using AI tutoring tools report improved student satisfaction and lower dropout rates (WiFiTalents, 2025).

AI and robotics have been widely adopted in the U.S., UK, Germany, and China for administrative workflows, student support, analytics, and resource management. These technologies have proven effective in improving operational efficiency, student outcomes, and institutional capacity. Moreover, ethical frameworks and governance policies in these regions help ensure responsible, scalable, and sustainable AI deployment in education.

State of AI and Robotics Adoption in Nigeria

Current Status: What Is Being Used and Where?

- a) Dedicated AI courses are offered in only 12% of federal universities, often as outdated theoretical lectures without modern hardware, GPUs or stable internet (Nigeria Education News, 2025).
- b) A few universities are experimenting with chatbots, virtual assistants, and e-libraries, particularly at National Open University of Nigeria (NOUN), though most lack institutional capacity to scale these systems (Learnetric, 2024; SZT Dev, 2024).
- c) Early e-examination systems with fingerprint biometrics and encryption exist in at least six universities, but these remain isolated pilots rather than system-wide deployments (Adebayo & Abdulhamid, 2014).
- d) Limited robotics engineering programs are available in select polytechnics and universities, yet practical labs are hampered by funding shortages and faculty gaps (LearnersRoom, 2025).

Role of Institutions & Government Agencies

- a) At least three tertiary institutions Obafemi Awolowo University, Lagos State University, and Federal University of Technology Minna were recognized in 2025 for having AI policies or leading AI application awards (NUC-NOUN AI Awareness Day communiqué, Feb17,2025).

- b) Delta State University Abraka (DELSU) is finalizing an institutional AI policy to guide AI use across teaching, research, administration, and community outreach (Ebireri et al., 2024).
- c) National-level coordination comes via NUC, NOUN, TETFund, VICBHE, NAAIP, and the Association of African Universities, all advocating for AI awareness, policy development, capacity building, and research ecosystem strengthening (NOUN News / Tribune, Feb,2025).
- d) Government initiatives include the 3 million Technical Talent (3MTT) programme launched in 2023 by NITDA, targeting training of 3 million Nigerians in AI and related fields by 2027 (3MTT initiative).
- e) The federal government also launched the Free AI Academy with partners like Commonwealth Secretariat and Intel, and is reviewing a National AI Strategy to guide education and public-sector deployment (Reddit / government announcement, Jan,2025).
- f) Stakeholders have emphasized the need for a national AI law and policy, noting deficient infrastructure, high implementation costs, and regulatory gaps (Tribune Online, 2025).

Challenges

- a) **Infrastructure gaps:** Inadequate internet connectivity, unstable power, and lack of computer hardware like GPUs significantly limit AI deployment (Anejumo & Okeke, 2022; NITDA study, 2025).
- b) **Funding and staffing constraints:** Many universities cannot afford AI faculty, labs, or tools. A shortage of qualified AI educators also persists (BusinessDay NG, 2024).
- c) **Policy absence:** Though institutional policies are emerging, Nigeria lacks a binding national education AI policy to drive standardized institutional adoption (NUC communique; Guardian Nigeria, 2025).
- d) **Digital literacy:** Students and staff often lack the skills to use AI tools meaningfully; rote teaching dominates rather than interactive or AI-based methods (Nigeria Education News, 2025).
- e) **Resistance to change:** Faculty concerns about job displacement and ethical implications hinder adoption; insufficient training compounds this reluctance (Scribd handbook / Adejumo & Okeke, 2025).
- f) **Inequity and inclusivity:** Urban institutions show some progress; rural and low-income students are underserved due to connectivity and equipment barriers (Nigeria Education News, 2025).

Comparative Analysis**Comparison: Developed Countries vs Nigeria**

Dimension	Developed Countries (U.S., UK, Germany, China)	Nigeria (incl. Northern & Public Schools)
Readiness	Well established digital infrastructure, institutional AI policies, faculty training; national AI strategies widely adopted (TechRadar, 2024; Kiplinger, 2024; Business Insider, 2024).	Readiness is low. Northern state universities show poor infrastructure, low teacher readiness, limited curriculum integration, and weak student engagement (Yakubu & Anigbogu, 2024).
Implementation	AI chatbots, analytics, grading automation, and library ML systems are widely in use (Basken, 2025; TechRadar, 2024; Times of India, 2024).	Isolated pilots: basic chatbots, early biometric e-exams, and few robotics labs; minimal scale (Yakubu & Anigbogu, 2024; Ibhafidon & Omoregie, 2024).
Outcomes	Improved student retention, faster administrative services, enhanced engagement, and early policy frameworks for ethics & fairness (Basken, 2025; TechRadar, 2024; Jin et al., 2024).	Results limited: some awareness of AI among school principals, but no measurable efficiency gains yet; adoption is largely dependent on individual initiative (Ibhafidon & Omoregie, 2024; Yakubu & Anigbogu, 2024).

Policy & Strategic Frameworks: What Nigeria Can Learn

- a) **Explicit Institutional Policies:** Universities in the U.S. and Europe have developed generative-AI governance frameworks that define faculty autonomy, student responsibilities, and system oversight (Jin et al., 2024). Nigeria should pursue similar institutional and national frameworks.
- b) **National Coordination:** Developed countries benefit from cohesive national AI strategies such as the UK AI Act, Germany's National AI Strategy, and China's central education mandates. Nigeria must accelerate its National AI Strategy to include institutional guidance and enforcement mechanisms (TechRadar, 2024).
- c) **Curriculum & Teacher Training:** In India and the U.S., teacher populations now receive formal AI literacy training through government-backed professional development programs (Times of India, 2024). Nigeria should mandate similar training programs to equip educators with the necessary skills.

Stakeholder Involvement: Private Sector, Government & Institutions

- a) **Government:** Developed nations combine regulatory guidance, financial grants, and mandates. For example, the U.S. Department of Education provides AI grants, the UK has enacted AI legislation, and Germany funds AI through the DigitalPakt Schule program (Times of India, 2024; TechRadar, 2024).

In Nigeria, agencies such as NUC, NOUN, TETFund, and NAAIP, alongside the AI Academy and 3MTT Programme, coordinate early-stage initiatives but lack binding national enforcement (The Nation, 2025; Reddit, 2025).

- b) **Private Sector & Academia:** In developed countries, universities collaborate with tech firms such as OpenAI, Microsoft, and Century Tech to pilot and scale AI applications (TIME, 2024).

In Nigeria, private-sector involvement is nascent, with projects like Wini University and public-private training programs showing potential but limited reach (Reddit, 2025).

- c) **Institutional Leadership:** Leaders in top universities in developed countries (e.g., Harvard) establish AI ethics committees, working groups, and training programs (Basken, 2025; Jin et al., 2024).

In Nigeria, while some principals such as those in Edo State have initiated AI awareness campaigns, many institutions lack structured AI governance mechanisms (Ibhafidon & Omoregie, 2024; Yakubu & Anigbogu, 2024).

Key Takeaways

- a) **Structural Readiness:** Advanced countries demonstrate robust readiness through clear policies, infrastructure, and faculty development, while Nigeria faces foundational gaps.
- b) **Implementation Scale:** Automation and AI-assisted workflows are mainstream in developed nations but remain fragmented in Nigeria.
- c) **Strategic Partnerships:** Private sector, government, and universities collaborate extensively abroad, whereas Nigeria needs to develop a stronger multi-sector ecosystem.

By adopting national AI governance frameworks, investing in infrastructure, empowering educators through professional training, and encouraging private-public collaboration, Nigerian institutions could transition from pilot programs to operational maturity in AI-driven educational administration.

Barriers and Opportunities in Nigeria

Infrastructure & Funding Gaps

Nigeria's northern universities largely lack reliable digital infrastructure modern computing equipment, stable power, dependable internet which constrains any substantive AI deployment (Suleiman & Muktar, 2020; World Bank, 2019). Financial limitations impede investments in hardware, software licensing, and infrastructure upgrades (Suleiman & Muktar, 2020).

Bureaucratic delays and procurement inefficiencies further worsen progress while corruption undermines funds meant for technological improvements (Suleiman & Muktar, 2020; Usman, 2020).

Human Capacity & Digital Readiness

There is a severe shortage of trained AI professionals and educators capable of integrating AI tools into pedagogy (PwC Nigeria; Tech ecosystem review, 2024). Low digital literacy among teachers and students is widespread 68% of teachers report minimal AI competency and struggle to utilize digital tools effectively (Adolph, 2025). Furthermore, many students must resort to external platforms like YouTube or Coursera due to lack of institutional resources.

Cultural & Institutional Resistance

Faculty and administrative resistance stem from job security concerns, ethical anxiety, and unfamiliarity with AI (Suleiman & Muktar, 2020). Institutional inertia and lack of leadership around AI initiatives result in patchy or pilot-only adoption, mostly driven by individual advocacy rather than institutional strategy (Ibhafidon & Omoregie, 2024; Yakubu & Anigbogu, 2024). Weak regulatory frameworks exacerbate fears around data misuse, algorithmic bias and privacy violations.

Opportunities for Leapfrogging

Despite these barriers, Nigeria has significant potential to leapfrog stages of development by embracing AI strategically. The concept is supported by international evidence suggesting that AI can help developing nations bypass traditional phases of digital growth (Financial Times, 2024). Several emerging Nigerian initiatives reinforce this promise:

- a) 3 Million Technical Talent (3MTT) programme and Microsoft partnerships are training millions in AI, data science, and cybersecurity across all states (PwC Nigeria; 3MTT documentation, 2023–24).
- b) Public-private collaboration, such as Microsoft AI Skilling Initiative, Nigeria Women Techsters, and Elite□Global□AI workshops in Edo State, deliver practical training and connect youth with global opportunities (BusinessDay; Efuetaanu & Elite Global AI).
- c) EdTech platforms like Afrilearn and Solve Education’s Telegram ‘Ed the Bot’ extend personalized learning and literacy support to underserved communities via accessible mobile interfaces (Wikipedia; Solve Education documentation).
- d) Localized innovation labs such as SuaCode and AutoGrad are developing AI tools tailored to African educational needs, enabling hands-on coding and automated feedback for students (Boateng, 2024).

Summary Table

Barrier	Detail
Infrastructure	Outdated hardware, poor internet, inconsistent power (Suleiman & Muktar, 2020)
Funding	Insufficient and delayed funding, bureaucratic hindrance (Suleiman & Muktar, 2020)
Human Capacity	Few AI-trained staff; low digital literacy (Adolph, 2025; PwC Nigeria)
Cultural Resistance	Job insecurity, ethical concerns, slow institutional adoption
Opportunities	National training (3MTT), partnerships, mobile AI platforms, coding labs (EdTech, 3MTT, Boateng, 2024)

Recommendations

Roadmap for AI & Robotics Adoption

- a) **Adopt the National AI Strategy (NAIS):** Finalize and implement Nigeria's Draft National AI Strategy which sets vision, governance, economic, and educational goals and align adoption across ministries, institutions, and states (Tech Policy Advisory, 2024).
- b) **Create tiered institutional benchmarks:** Define clear targets for tertiary and secondary institutions (e.g., minimal infrastructure thresholds, chatbot usage, e-exams, and robotics labs) linked to accreditation or grants.
- c) **Monitor & fund innovation through NAIRS:** Use Nigeria Artificial Intelligence Research Scheme grants to support AI pilots in education and track outcomes against benchmarks (Dataphyte, 2023).

Capacity-Building Strategies

- a) **Scale up 3MTT Programme:** Expand upskilling via the 3MTT initiative which has already delivered AI training to hundreds of thousands toward its 3 million targets, partnering with universities and training centres (Wikipedia / 3MTT, 2023).
- b) **Embed AI in teacher training:** Integrate AI literacy and applied robotics into curricula for Colleges of Education and teacher institutes; offer short immersive AI-cybersecurity bootcamps, especially for rural teachers (PM News, 2025).
- c) **Create local educator workshops:** Support initiatives like AI for Educators Initiative which has trained hundreds of primary and secondary teachers in Kebbi and Ebonyi to serve as scalable training hubs (Tribune Online, 2025).

Institutional Partnerships & Policy Support

- a) **Promote public-private collaboration:** Foster partnerships among universities, EdTech firms (e.g. Afrilearn, Solve Education), training hubs, and corporates (e.g. Microsoft, Google) to co-develop adaptive learning, AI-assistants, and infrastructure (AllAfrica, 2024; BusinessDay, 2024).

- b) **Establish ethical governance & policies:** Encourage institutions to adopt generative-AI policies on usage, privacy, and plagiarism as seen in leading global universities and to set up AI ethics committees (Lawanson, 2025).
- c) **Enact national AI education law:** Build on calls (e.g., Professor Lawanson and AI Awareness Day stakeholders) for a binding AI policy in education that defines funding, curriculum integration, infrastructure support, and institutional accountability (Tribune, 2025; Independent, 2025).

Integration with National ICT Strategy

- a) **Leverage USPF for rural connectivity:** Utilize the Universal Service Provision Fund to extend broadband and ICT infrastructure in underserved public schools, enabling AI and robotics use in remote areas (Wikipedia / USPF, 2024).
- b) **Coordinate through NITDA and ITF:** Engage NITDA's AI training leadership (capacity building, policy alignment) and the Industrial Training Fund's skills development infrastructure to embed AI across education and vocational systems (NITDA, 2025; ITF 2024 budget report).
- c) **Regional alignment through ECOWAS:** Align Nigeria's educational AI plans with ECOWAS's ECOPOST goals and the Pan-African AI Strategy to encourage cross-border collaboration and resource sharing (Reddit summary, 2024).

Conclusion

This paper examined the adoption of artificial intelligence (AI) and robotics in enhancing seamless academic operations within educational institutions, comparing developed nations with Nigeria particularly the northern region. Evidence from the United States, United Kingdom, Germany, and China demonstrates that AI has become an integral part of student administration, grading automation, predictive analytics, and institutional management, leading to improved efficiency, retention, and service delivery (Basken, 2025; TechRadar, 2024; Jin et al., 2024). In contrast, Nigeria's progress remains constrained by inadequate infrastructure, insufficient funding, limited human capacity, and resistance to change (Yakubu & Anigbogu, 2024; Suleiman & Muktar, 2020). However, the findings also highlight opportunities for strategic leapfrogging. National programs such as the 3MTT initiative, the emerging National AI Strategy, and grassroots EdTech innovations present a pathway for Nigeria to bypass some traditional stages of technological evolution by adopting scalable and context-specific AI applications (Dataphyte, 2023; PwC Nigeria, 2024). Successful implementation will require coordinated policy frameworks, institutional leadership, capacity building, and sustained partnerships between government, academia, and the private sector (Lawanson, 2025; Tribune Online, 2025). Bridging the technological gap in academic operations between Nigeria and advanced countries is not merely a matter of technology acquisition but of ecosystem alignment. By integrating AI and robotics within a robust policy environment, developing digital skills for educators and administrators, and leveraging both national and international collaborations, Nigeria can transform its educational administration and create a future-ready academic system. If pursued decisively, these efforts will not only enhance operational efficiency but also prepare the Nigerian education sector to thrive in the rapidly evolving digital era.

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APPLICATION OF STEM EDUCATION ARTIFICIAL INTELLIGENCE TECHNOLOGIES AND INTERNET ADDICTION ON THE ACADEMIC PERFORMANCE OF STUDENTS IN SCIENCE AND TECHNICAL COLLEGES IN NORTH CENTRAL NIGERIA

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Introduction

Science, Technology, Engineering, and Mathematics education (STEM) in Nigeria aims to dissect the complexities, challenges, and opportunities within this educational sector, particularly in the context of global educational trends and national developmental imperatives, with a keen focus on aligning it with global standards. STEM education is an interdisciplinary learning approach that combines Science, Technology, Engineering, and Mathematics to foster critical thinking, problem-solving, creativity, and innovation. The Core Disciplines area: Science, Technology, Engineering, and Mathematics. These are Science Biology, Chemistry, Physics, and Earth Sciences: Technology: Computer, Science, Information Technology, Engineering, and Robotics:Engineering: Mechanical, Electrical, Civil, and Aerospace Engineering:Mathematics: Pure Mathematics, Applied Mathematics, Statistics, and Data Analysis

According to Abdulraheem-mustapha (2021), STEM education refers to teaching and learning of the discipline of science, technology, engineering and mathematics in an integrated nature. Aina, Abdulrahman and Ayodele (2020) observe that STEM education promotes an interdisciplinary approach that encourages students to apply knowledge and skills across different domains. STEM education aims to provide students with a comprehensive understanding of these disciplines, fostering critical thinking, problem-solving, creativity, and innovation. Ugo and Akpoghol (2016) point out the Importance of STEM Education to include; Prepares students for careers in high-demand fields; develops critical thinking, problem-solving, and creativity skills; Enhances collaboration and communication skills; Fosters innovation and entrepreneurship and Addresses real-world challenges and problems According to Umar (2019), STEM Education is characterised by the following; Interdisciplinary approach, Hands-on, project-based learning, Emphasis on critical thinking and problem-solving, Integration of real-world applications and examples Focus on developing skills for the 21st-century workforce

Aina, Abdurrahman and Ayodele point out that STEM Education in Nigeria has been from the year of independence to date, and several studies have attributed the challenges of sustainable development in Nigeria to the issues related to STEM education. The application of STEM and AI is vast and transformative. STEM Education and AI Interplay enables the development of robust AI technologies, equipping students with critical analytical and technical skills. This integration fosters innovation, creativity, and problem-solving, which are essential for addressing complex challenges. According to Bal and Bedir (2021), the applications of STEM and AI include: Healthcare: AI algorithms analyse medical data for diagnostics, personalise treatment plans, and facilitate robotic surgeries, enhancing patient outcomes and operational efficiency; Finance: AI-driven tools utilise data analytics to predict market trends, assess risk, and automate trading processes, leading to more

informed decision-making and increased profitability; Transportation: Autonomous vehicles rely heavily on AI technologies, powered by STEM-based research, utilising sensors and algorithms to navigate, optimise routes, and improve safety and Education: Customised learning experiences are created using AI to cater to individual student needs, enhancing engagement and knowledge retention¹.

According to Yeboah (2020). The future of STEM and AI holds immense potential, with emerging trends like personalised learning experiences, interdisciplinary studies, and the rise of online learning platforms. As AI continues to evolve, it's essential to address the challenges in STEM education, such as resource limitations, teacher training, and curriculum development. The relevance of Nigerian STEM (Science, Technology, Engineering, and Mathematics) education in the global context is a multifaceted issue, encompassing economic growth, human skills development, and the integration of global educational trends.

Artificial Intelligence (AI)

Digitalisation and artificial intelligence (AI) are changing the way individuals work, live, communicate, learn and play. Whether they are aware of it or not, individuals are increasingly encountering advanced technologies such as AI in their everyday lives, in exchanges as diverse as applying for a loan and scrolling through social media, some of which may have a profound impact on their lives. According to Glaveanu, Ness, Wasson, & Lubart. (2019). Digital technology has made a distinctive contribution to fostering students' creativity and student engagement by providing new tools and environments for learning to be creative, and learning through being creative

The internet has evolved into a central pillar of modern life, reshaping how people communicate, access information, and perform daily tasks. Globally, over 5.4 billion people are now internet users, with adolescents and young adults forming a significant portion of this population (International Telecommunication Union [ITU], 2023). In the views of Kuss & Lopez-Fernandez (2016), the internet offers unparalleled educational opportunities, social connectivity, and access to information; its excessive and uncontrolled use has led to a growing public health concern known as internet addiction. While Yang-Heim and Dobson (2023) referred to teachers or teacher candidates and their students as digital natives, because these young people grow up in an era characterised by the ubiquity of technology, and they have become accustomed to using technological devices for various purposes, including information gathering, communication, and entertainment. According to ITU (2023), on the African continent, internet penetration continues to rise rapidly, with over 43% of the population now online, primarily through mobile technology. This surge is especially pronounced among the youth, who use the internet not only for educational purposes but also for entertainment and social interaction. However, Dawodu, Adeyemi and Kehinde (2023) revealed that studies across African countries have highlighted an increasing trend of problematic internet use among secondary school students, with consequences for their academic, emotional, and social well-being.

In Nigeria, internet access has expanded significantly over the past two decades, driven by the affordability of mobile data and government investment in digital infrastructure. According to the Nigerian Communications Commission (NCC) (2023), over 150 million Nigerians currently use the internet, with adolescents representing a growing user segment. Mohammed and Abdulwasiiu

(2017) point out that despite the opportunities this expansion provides for academic development, emerging evidence suggests that excessive and unregulated internet use may undermine students' academic goals by promoting procrastination, distraction, and sleep deprivation. North Central Nigeria has witnessed an upsurge in AI and internet usage among Students in Science and Technical Colleges, with access to smartphones and social media platforms becoming more widespread. Concerns have emerged among educators and parents about the potential effects of internet overuse on students' academic performance. However, there remains a paucity of empirical studies that systematically examine the link between AI, internet addiction and academic outcomes within this specific context. Caminiti (2020). Explain that AI and internet addiction are characterised by excessive or poorly controlled preoccupations, urges, or behaviours regarding computer use and internet access that lead to impairment or distress. It encompasses various dimensions, including compulsive browsing, social media overuse, online gaming, and cyber-relationship addiction. Therefore, the increasing internet penetration and academic pressures faced by students in science and technical colleges in north central Nigeria, a rigorous empirical inquiry into how AI and internet addiction affect academic performance is both timely and necessary. This study seeks to fill the existing gap by systematically analysing the dimensions and consequences of AI and internet addiction among this population, with a view to informing policy and educational interventions.

Statement of the Problem

The digital revolution has transformed educational landscapes worldwide, presenting both opportunities and challenges for students. While internet access provides a platform for knowledge acquisition, research collaboration, and academic innovation, AI refers to Artificial Intelligence, while its excessive or maladaptive use is commonly referred to as internet addiction, and has emerged as a significant concern, particularly among adolescents. According to Kuss & Lopez-Fernandez (2016), internet addiction is associated with declining academic performance, impaired cognitive functioning, and reduced academic motivation. The extent to which this phenomenon manifests in specific local contexts among students of science and technical colleges in North Central Nigeria remains underexplored. The rapid growth of AI and internet access, in particular, is increasingly reliant on the Internet for both academic and non-academic purposes. Educators and parents in North Central Nigeria worried about a rising trend of problematic internet use among students, characterised by late-night browsing, excessive social media activity, online gaming, and distraction during study time. Therefore, this study seeks to fill a significant knowledge gap by investigating the Application of STEM Education, AI Technologies and Internet Addiction on the Academic Performance of Students in Science and Technical Colleges in North Central Nigeria. The findings are expected to provide insights that will guide educators, policymakers, school administrators, and mental health professionals in implementing evidence-based strategies to enhance student performance and digital well-being.

Purpose of the Study

The primary purpose of this study is to investigate the Application of STEM Education, AI Technologies and Internet Addiction on the Academic Performance of Students in Science and Technical Colleges in North Central Nigeria. Specifically, the study seeks to:

- i. Identify the types of STEM Education for students in science and technical colleges in North Central Nigeria.

- ii. Identify the types of AI and internet facilities available for students in science and technical colleges in North Central Nigeria.
- iii. Challenges of AI and internet addiction on the academic achievements of students in science and technical colleges in North Central Nigeria.

Research Questions

- i. What types of STEM Education are available to students in science and technical colleges in North Central Nigeria?
- ii. Identify the types of AI and internet facilities for students in science and technical colleges in North Central Nigeria?
- iii. What are the Challenges of AI and internet addiction on the academic achievements of students in STC in North Central Nigeria?

Hypotheses

H₀₁ There is no significant difference between federal STC and state STC on the types of STEM Education for students in science and technical colleges in North Central Nigeria.

H₀₂ There is no significant difference between federal STC and state STC on the Challenges of types of STEM Education, AI and internet addiction on the academic achievements of students in North Central Nigeria

Methodology

This study adopts a descriptive survey research design. According to Fraenkel, Wallen, & Hyun (2012). A descriptive survey is used to systematically collect information from a sample to describe characteristics, behaviours, or relationships within a population. This design is particularly suitable for educational and social science research where variables are not manipulated but observed as they occur naturally. The area of this study is North-Central Nigeria.

The population of this study comprises all science and technical colleges owned and controlled by the Federal and State Governments in North-Central Nigeria, and students in SS1 to SS3. A multistage sampling technique was employed in this study. These six schools were chosen to provide a fair representation of the student population in both federal and state STCs across North-Central Nigeria. 400 students were distributed equally across the two strata, with 200 students drawn from the federal STC and 200 from the State STC. These students chosen at this educational level are highly exposed to the Internet for both academic and recreational purposes, making them susceptible to varying degrees of Internet use and potential addiction. A well-structured questionnaire as an instrument for data collection was used. Two experts in computer studies and one in tests and measurement from the Faculty of Education, Benue State University, Makurdi, had a face and content validation of the questionnaire in terms of clarity, relevance and structure. The internal consistency of the instrument was measured using the Cronbach's Alpha technique, and it yielded a reliability coefficient of 0.82, indicating a high level of internal consistency. The four-point Likert-type scale of SA (4), Agree (3), Disagree (2) and Strongly Agree (1) was employed in the design of the instrument, which contained 30 items. The result of the study was

analysed using Statistical Package for the Social Sciences (SPSS) version 23. The results with mean ratings between 0 and 2.49 were considered as disagreement, and agreement when they fell between 2.50 and above.

Data Analysis and Results

This section presents the analysis of data collected from respondents using descriptive and inferential statistics. Out of 400 distributed questionnaires, 388 were correctly completed and returned, yielding a response rate of 97%.

Table 1: Socio-Demographic Characteristics of the Respondents

S/No	Variable	Frequency	Valid Per cent
1. Age			
	12–14	68	17.5%
	15–17	202	52.1%
	18–21	118	30.4%
2. Gender			
	Female	229	59.0%
	Male	159	41.0%
3. Class Level			
	SS1	99	25.5%
	SS2	180	46.4%
	SS3	109	28.1%
4. Type of School			
	Federal	172	44.3%
	State	216	55.7%

Source: Field Survey (2025)

Table 1 presents the socio-demographic characteristics of the respondents. Findings reveal that the majority (52.1%) of the respondents were between the ages of 15–17 years, followed by those aged 18–21 years (30.4%), and the least proportion (17.5%) was between 12–14 years. In terms of gender, 59.0% of the respondents were female, whereas 41.0% were male. Regarding class level, most of the students (46.4%) were in SS2, followed by those in SS3 (28.1%), and the remaining 25.5% were in SS1. The type of school attended revealed that a majority (55.7%) were enrolled in Federal STC, while 44.3% were in State STC.

Research question 1: What types of STEM Education are available to students in science and technical colleges in North Central Nigeria?

Table 2: Responses of students regarding the types of STEM Education, AI and internet facilities available for students' concentration among STC in North Central Nigeria

S/No:	Items (Responses)	No:	Percentage (Yes)
6.	Access to Science: e.g. Biology, Chemistry, Physics	265	68.3%
	Earth Sciences	123	31.7%
7.	Access to Technology: Computer Science	73	18.8%
	Information Technology	315	81.2%
	Engineering, and Robotics	117	30.2%
8.	Engineering: Mechanical, Electrical, Civil	128	33.0%
	Aerospace Engineering	46	11.9%
9.	Mathematics: Pure Mathematics	97	25.0%
	Applied Mathematics	12	3.1%
	Statistics	40	10.3%
	Data Analysis	238	61.3%

With respect to access to Science: 68.3% of respondents reported having internet access Biology, Chemistry, Physics whereas 31.7% have access to Earth Sciences Technology: A significant majority (81.2%) identified Computer Science, whereas 18.8% have access to Information Technology they 30.2% identified Engineering, and Robotics, 33.0% of respondents identified Engineering: Mechanical, Electrical, Civil, and 11.9% for Aerospace Engineering 25.0% identified Mathematics: 25.0% identified Pure Mathematics, 3.1% Applied Mathematics, 10.3% identified Statistics, and 61.3% identified Data Analysis

Research question 2: Identify the types of AI and internet facilities for students in science and technical colleges in North Central Nigeria.

Table 3: Responses of students regarding the availability of AI and internet facilities for students in science and technical colleges in North Central Nigeria

S/No:	Items (Responses)	No:	Percentage (Yes)
10.	Access to Internet at	123	31.7%
	Home	265	68.3%
	School	73	18.8%
11.	Smartphone/Device	315	81.2%
12.	Daily Internet Usage (in hours)		
	Less than 1	46	11.9%
	1 - 2	97	25.0%
	3 - 4	128	33.0%
	5 and above	30	2%
13.	Pays for Internet Access		
	Others	12	3.1%
	Parents/Guardian	238	61.3%
	School	40	10.3%
	Self	98	25.3%

With respect to internet access, 68.3% of respondents reported having internet access at home, whereas 31.7% did not. A significant majority (81.2%) indicated that they owned a smartphone or internet-enabled device, while only 18.8% did not. On daily internet usage, 33.0% of respondents reported using the internet for 3–4 hours daily, followed by 30.2% who used it for 5 hours or above, 25.0% used it for 1–2 hours, and 11.9% reported usage of less than 1 hour per day. In terms of who pays for their internet access, the majority (61.3%) said it was sponsored by their parents or guardians, while 25.3% paid for it themselves. 10.3% received support from their schools, and a small proportion (3.1%) indicated others as their source.

Research question 3: What are the Challenges of AI and internet addiction on the academic achievements of students in STC in North Central Nigeria?

Table 4: responses of students on Challenges of AI and internet addiction on Academic Achievement

S/No:	Item Statement	SD	D	AS	A	χ^2
11	Declined academic performance	36 (9.3%)	36 (9.3%)	121 (31.2%)	3.62 (29.1%)	113
12	low grades	28 (7.2%)	27 (7.0%)	110 (28.4%)	133 (34.3%)	3.85
13	poor performance in tests	40 (10.3%)	41 (10.6%)	115 (29.6%)	116 (29.9%)	3.58
14	Negative impact on Academics	39 (10.1%)	36 (9.3%)	118 (30.4%)	118 (30.4%)	3.61
15	More time spent online	42 (10.8%)	46 (11.9%)	110 (28.4%)	3.54 (29.4%)	114
16	Low academic performance	40 (10.3%)	37 (9.5%)	118 (30.4%)	116 (29.9%)	3.60
17	Lower marks than expected	39 (10.1%)	35 (9.0%)	116 (29.9%)	121 (31.2%)	3.63
18	Skipped classes	46 (11.9%)	44 (11.3%)	124 (32.0%)	110 (28.4%)	3.54
19	Failed subjects or tests	34 (8.8%)	39 (10.1%)	116 (29.9%)	121 (31.2%)	3.64
20	Academic goals affected	44 (11.3%)	39 (10.1%)	132 (34.0%)	105 (27.1%)	3.56

Source: Field Survey (2025)

Table 4 presents the responses of students regarding the Challenges of AI and internet addiction regarding Academic Achievement. The analysis shows that 9.3%, 9.3%, 21.1%, 31.2%, and 29.1% of the respondents strongly disagreed, disagreed, were neutral, agreed, and strongly agreed, respectively, that their academic performance has declined due to frequent internet use. Likewise, 7.2%, 7.0%, 23.2%, 28.4%, and 34.3% of the respondents strongly disagreed, disagreed, were neutral, agreed, and strongly agreed, respectively, that they would get better grades if they spent less time online. Additionally, 10.3%, 10.6%, 19.6%, 29.6%, and 29.9% of the respondents strongly disagreed, disagreed, were neutral, agreed, and strongly agreed, respectively, that they have performed poorly in tests due to distractions from internet use. In a similar pattern, 10.1%, 9.3%, 19.8%, 30.4%, and 30.4% of the respondents strongly disagreed, disagreed, were neutral, agreed, and strongly agreed, respectively, that their internet habits have negatively affected their academics.

Further analysis reveals that 10.8%, 11.9%, 19.6%, 28.4%, and 29.4% of the respondents strongly disagreed, disagreed, were neutral, agreed, and strongly agreed, respectively, that they miss academic deadlines due to time spent online. Also, 10.3%, 9.5%, 19.8%, 30.4%, and 29.9% of the respondents strongly disagreed, disagreed, were neutral, agreed, and strongly agreed, respectively, that their teachers have noticed a drop in their academic performance. In terms of examination outcomes, 10.1%, 9.0%, 19.8%, 29.9%, and 31.2% of the respondents strongly disagreed, disagreed, were neutral, agreed, and strongly agreed, respectively, that they got lower marks than expected due to a lack of preparation caused by internet use. Additionally, 11.9%, 11.3%, 16.5%, 32.0%, and 28.4% of the respondents strongly disagreed, disagreed, were neutral, agreed, and strongly agreed, respectively, that they have skipped classes because they were online late at night. Also, 8.8%, 10.1%, 20.1%, 29.9%, and 31.2% of the respondents strongly disagreed, disagreed, were neutral, agreed, and strongly agreed, respectively, that they have failed subjects or tests due to a lack of study caused by internet addiction. Lastly, 11.3%, 10.1%, 17.5%, 34.0%, and 27.1% of the respondents strongly disagreed, disagreed, were neutral, agreed, and strongly agreed, respectively, that their academic goals are negatively affected by their internet use habits. The mean analysis revealed that items 1-10 had mean scores of 3.62, 3.85, 3.58, 3.61, 3.54, 3.60, 3.63, 3.54, 3.64, and 3.56, respectively. Since all mean scores are above 3.0, it means that we accept that the student's academic performance has declined due to frequent AI/internet use.

Hypotheses

H0₁: There is no significant difference between federal STC and state STC in the types of AI and internet facilities available for students' concentration

H0₂: There is no significant difference between federal STC and state STC on the Challenges of AI and internet addiction on the academic achievements of students in STC in North Central Nigeria

Table 5: Responses of students regarding the availability of AI and internet facilities for students' concentration among STC in North Central Nigeria.

R ²	Adjusted R ²	Std. Error	F	B (Unstd.)	SE B	Beta (Std.)	t	Sig. (p)
.226	.224	3.41537	1330.057	-0.528	0.049	-0.475	-10.681	.000

Source: Field Survey (2025)

The regression analysis was conducted to examine the effect of internet addiction (as measured by the addiction scale) on students' concentration levels. The model summary reveals an R Square value of 0.226. This implies that approximately 22.6% of the variance in concentration scores can be explained by students' levels of internet addiction. The adjusted R Square, which accounts for the number of predictors in the model, remains close to 0.224, reinforcing the consistency of the model's explanatory power. The F-statistic is 1330.057, and the significance level (p-value) is less than 0.001. This indicates that the model provides a significantly better fit to the data than a model with no predictors, thus confirming that the addiction scale is a meaningful predictor of concentration. The unstandardized coefficient (B) for the addiction scale is -0.528 with a standard error of 0.049. This means that for every one-unit increase in the addiction score, students' concentration scores decrease by approximately 0.528 units. The negative sign indicates an inverse relationship. Moreover, this effect is statistically significant ($t = -10.681$, $p < 0.001$), confirming

that the impact of internet addiction on concentration is not due to chance. The analysis demonstrates a statistically significant and negative impact of internet addiction on students' concentration.

Table 6: The responses of students on Challenges of AI and internet addiction regarding the Academic Achievement

R²	Adjusted R²	Std. Error	F	B (Unstd.)	SE B	Beta (Std.)	t	Sig.	(p)
.220	.217	3.13842	130.590	-0.635	0.076	-0.469	-11.426	.000	

Source: Field Survey (2025)

A regression analysis was carried out to determine the impact of internet addiction (measured by the addiction scale) on students' study time. The model summary shows an R Square value of 0.220, indicating that 22.0% of the variability in students' study time can be accounted for by their level of internet addiction. The adjusted R Square value is 0.217, which slightly adjusts for the sample size and number of predictors, confirming the model's reliability. The F-statistic for the model is 130.590 with a p-value less than 0.001, suggesting that the model is statistically significant and provides a much better fit than a model without predictors. This means that AI/ internet addiction significantly predicts changes in study time.

The unstandardized coefficient (B) for the addiction scale is -0.635 with a standard error of 0.076. This suggests that for every one-unit increase in internet addiction, students' study time decreases by approximately 0.635 units. The negative value indicates a clear inverse relationship. The standardised coefficient (Beta) is -0.469, and the t-value is -11.426, with a p-value less than 0.001. This confirms that the relationship is statistically significant and unlikely to have occurred by chance.

Discussion of Findings

The findings of the current study revealed a high prevalence of AI /internet addiction among students in STC in North Central Nigeria. Most respondents admitted to compulsive AI /internet use, such as staying online longer than intended, neglecting schoolwork, and experiencing difficulty controlling their screen time. These behaviours indicate that AI /internet addiction is a significant issue among adolescents in the study area. This finding aligns with Odinka et al. (2023), who found that 36.3% of adolescents in Enugu exhibited moderate internet addiction, and a further 2.1% showed signs of severe addiction. They also observed that younger adolescents and those from lower socioeconomic backgrounds were more vulnerable, reinforcing the widespread and socially influenced nature of this issue.

The study also found that AI/ internet addiction negatively affects students' concentration. Many respondents admitted to being distracted by their phones during class. The study also reported that students had to re-read materials due to poor focus. They also reported daydreaming about being online. This supports the findings of Age & Echoda (2021), who reported that time spent on social media hurt the academic performance of senior secondary students in Makurdi, particularly due to classroom distractions and reduced study focus.

The study further revealed that students' study time was significantly disrupted by the Challenges of AI and the internet. Many respondents confessed to a delay in assignment submissions. They

also reported missing study groups, sacrificing sleep, and choosing AI/internet entertainment over reading. This is consistent with Ogunrinde et al. (2024), who reported that excessive AI and internet use negatively influenced students' sleep patterns, disrupted academic routines, and caused delays in completing schoolwork. Similarly, Adeyemi (2024) found that undergraduate students who exhibited signs of internet addiction reported reduced study time and poor academic planning, which led to lower performance outcomes.

The study also discovered that AI/ internet addiction adversely affected students' academic achievement. It revealed that many students indicated they had missed deadlines. The study also found that students reported skipping classes due to excessive use of AI/ internet. The study also found that students who were addicted to the AI/internet performed poorly in tests because of internet-related distractions. This aligns with the work of Biokuromoye (2023), who found a high prevalence (84.9%) of internet addiction among university students and linked this trend to academic and psychological challenges.

The regression analysis revealed that a statistically significant and negative impact of internet addiction on students' concentration, study time and academic achievements. This aligns with the findings of Sarkar (2023), who identified a negative correlation between social media addiction and academic achievement, indicating that students with higher addiction levels performed worse in school. This contradicts the finding of Ipem and Okwara-Kalu (2020), who found a positive correlation between internet addiction and academic performance, suggesting that in some cases, high internet usage may be academically beneficial.

Conclusion

The study highlights a broader and increasingly urgent concern regarding the digital well-being of adolescents in the modern educational landscape. The widespread availability and affordability of smartphones, mobile data, and internet-enabled devices have made digital access nearly ubiquitous among secondary school students. While the internet remains an invaluable resource for learning, research, communication, and skill development, its misuse, particularly for non-academic purposes such as social media, gaming, and entertainment, has emerged as a growing threat to students' academic progress and overall mental health. The addictive nature of online content, coupled with a lack of self-regulation skills among adolescents, often leads to excessive screen time, digital distractions, sleep disruption, and emotional dependency.

The following recommendations are made based on the findings of the study:

- i. School Administrators Should Integrate Digital Literacy into the Curriculum. They should design and implement structured digital literacy programs that educate students on responsible AI/internet use, time management, and the risks of AI/internet addiction.
- ii. Teachers should be trained to identify signs of internet addiction, such as lack of focus, persistent device use during lessons, and academic underperformance. They should provide guidance on how to balance online activities with academic tasks and incorporate technology in ways that support learning without encouraging dependency.

- iii. Education authorities, such as the Ministry of Education at the state and federal levels, should formulate and enforce policies that promote responsible AI/internet use among students. Addiction.

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INSIGHT INTO THE MULTI-PREDICTIVE FACTORS INFLUENCING ARTIFICIAL INTELLIGENCE (AI) ADOPTION IN UNIVERSITY ADMINISTRATION IN NORTH-CENTRAL NIGERIA

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Abstract

The use of artificial intelligence (AI) is fast taking over the academic terrain as well as other professions. It is also used in university system administration, though to a limited scope. This study sheds light on the various factors that influence the adoption of AI in university administrative systems in North-Central Nigeria. Using the Technology–Organization–Environment (TOE) framework and the Diffusion of Innovation (DOI) theory as a guide, the research explores key elements such as technological infrastructure, staff training and digital skills, perceived usefulness, organizational readiness, leadership support, and resistance to change. The paper examines the multi-dynamics of AI adoption in the university administrative system, specifically in North-central Nigeria. The categories of multi-predictive factors: technological and organizational readiness, influence of external environment and social attitudes towards adoption of AI are examined. The challenges of adopting AI in the university system, the panacea to the identified problems and the ethical implications are discussed. This study adds to the existing knowledge by emphasizing the complex interplay of technological, organizational, and human factors that shape AI adoption in higher education administration. The practical implications suggest that policymakers and university leaders should focus on enhancing digital infrastructure, building capacity, and implementing effective change management strategies to promote a sustainable AI-driven transformation.

Keywords: Artificial Intelligence, University Administration, Adoption, Multi-predictive Factors, North-Central Nigeria, TOE framework, DOI theory

Introduction

Artificial intelligence is regarded as a tool capable of easily composing, structuring, and disseminating expressions in the blink of an eye with minimal human intervention. Its application across various fields is becoming more widespread as the world recognises its multifaceted capabilities. Artificial intelligence has been used in recent settings especially in the education sector given its multi-dimensional abilities to simplify tasks, enhance learning (Mohammed et al., 2025a) and reduce stress. Beyond direct teaching uses, AI also plays a vital role in the administrative functions that support effective educational delivery. University administration handles academic and operational activities such as student enrolment, faculty coordination, financial management, and institutional planning. Good administration improves institutional efficiency, service delivery, and decision-making (Nwosu and Ekpe, 2022). Given the complexity of these tasks, incorporating advanced technologies like Artificial Intelligence offers significant potential for enhancing performance.

Artificial Intelligence (AI) adoption is increasingly seen as a vital element in promoting innovation and efficiency across various sectors, including education, healthcare, finance, and manufacturing. However, adopting AI technologies is complex and shaped by a wide range of factors rather than a single cause. This paper examines multiple predictive factors influencing AI adoption, highlighting the interaction between technological, organisational, environmental, individual, and

socio-cultural variables. Understanding these interconnected factors provides valuable insights for researchers, policymakers, and practitioners seeking to facilitate effective AI integration.

Conceptualizing Multi-Predictive Factors in AI Adoption

Multi-predictive factors refer to the diverse and interconnected elements that are likely to influence the adoption of AI technologies. Rather than viewing adoption through a unidimensional lens, contemporary research advocates a multi-faceted approach, recognising that technological readiness, organisational culture, regulatory environments, user attitudes, and societal norms converge to influence adoption decisions (Venkatesh *et al.*, 2003; Maroufkhani *et al.*, 2020). Mishra *et al.* (2022) assert that a holistic framework is necessary to capture the complex dynamics at play, proposing integrated models that encompass multiple predictive dimensions. Such frameworks enable more accurate predictive analytics and the formulation of targeted interventions to improve adoption rates.

Categories of Predictive Factors

Technological readiness, including the perceived usefulness, compatibility, complexity, and security of AI systems, significantly predicts organizational adoption (Alharthi *et al.*, 2023). Organizations are more inclined to adopt AI when the technologies promise substantial improvements over existing processes with manageable levels of complexity and risk.

Organizational readiness encompasses management support, financial and human resources, strategic alignment, and employee capabilities (Maroufkhani *et al.*, 2020). Effective leadership commitment and a skilled workforce are strong enablers for AI adoption. Organizational inertia or resistance, by contrast, can hinder technological integration even when external conditions are favourable (Dwivedi *et al.*, 2021).

The external environment, including regulatory pressures, competitive dynamics, and technological infrastructure, also plays a critical role (Borges *et al.*, 2021). Government regulations, in particular, can either serve as a catalyst or a hindrance to AI initiatives depending on the clarity, consistency, and forward-looking nature of the policies. At the micro-level, individual perceptions, trust in AI, perceived threat to employment, and personal innovativeness directly affect AI adoption (Jöhnk *et al.*, 2021). Employee scepticism or fear of job displacement can significantly slow down AI initiatives unless adequately addressed through training and change management strategies.

Broader cultural factors, including societal attitudes toward technology, national innovation indices, and ethical norms, influence organizational behaviour regarding AI adoption (Tarhini *et al.*, 2022). Cultures that value innovation and technological progress exhibit higher rates of AI adoption, while cultures with strong ethical concerns about AI may adopt a more cautious approach.

Interaction of Multi-Predictive Factors

In practice, predictive factors are not isolated but interact dynamically. For example, strong organizational leadership can counterbalance employee resistance, while an insufficiency of technological infrastructure may negate the benefits of favourable government policies. Therefore, AI adoption should be approached as a systemic transformation requiring harmonization across all

dimensions (Dwivedi *et al.*, 2021). In educational institutions, for instance, huge financial investments in AI technologies may fail if academic staff feel threatened or undervalued. This truly emphasizes the importance of addressing both structural and human elements concurrently (Jöhnk *et al.*, 2021).

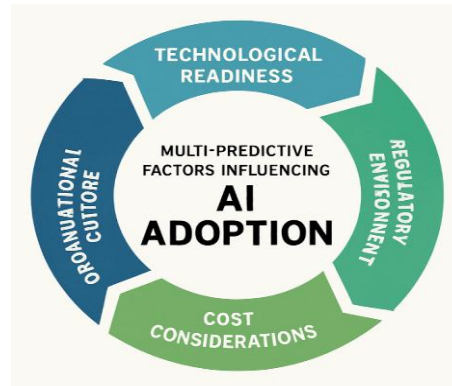


Figure 1: *Conceptual framework showing multiple predictive factors influencing AI adoption.*

The adoption of AI is a multi-factorial process influenced by a network of interacting technological, organizational, environmental, social-cultural factors and cost considerations. Understanding these multiple predictors is essential for crafting effective adoption strategies. Acknowledging and managing the interplay among these variables increases the likelihood of successful and sustainable AI integration. Future research must continue to explore integrated, context-sensitive models to accommodate the evolving complexities of AI technologies and organizational ecosystems.

AI integration in University Governance

The rapid evolution of societal, economic, and technological landscapes necessitates a transformative approach in aligning institutional goals in the university educational system. In North-Central Nigeria, this need is amplified by the region's socio-economic dynamics, demographic growth, and the advent of Artificial Intelligence (AI). Universities must innovate to remain relevant and impactful, leverage AI to meet the demands of a globalized economy, address local challenges, and enhance administrative, academic, and research outputs.

Integrating Artificial Intelligence (AI) into university governance can significantly enhance decision-making processes, operational efficiency, and policy implementation. The diagram below illustrates the flow of AI integration in university governance:

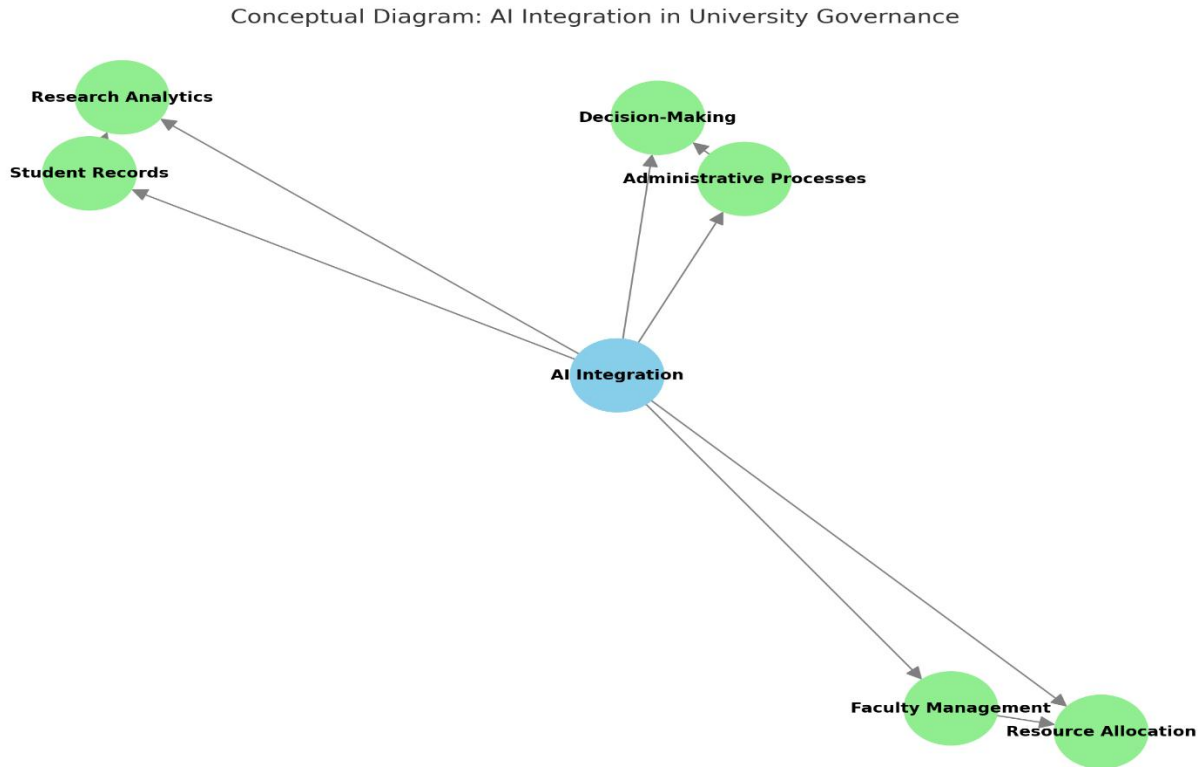


Figure 2: AI Integration in University Governance

Data Collection: Universities gather data from various sources, including student records, administrative processes, and academic performance metrics. A study on the readiness of higher education institutions in Northern Nigeria for AI integration highlights the potential of AI in enhancing data-driven decision-making processes. AI is revolutionizing data-driven decision-making in governance through a variety of powerful mechanisms. Predictive analytics, like modelling dropout risks and enrolment trends, allow for proactive interventions instead of just reacting to issues as they arise. Prescriptive analytics and optimization help with staff scheduling and budget planning by suggesting the best resource allocations based on simulated outcomes. Automated reporting and dashboards transform raw data from management information systems into actionable key performance indicators almost in real-time, giving leaders better visibility into operations. Natural language processing (NLP) tools dig into qualitative feedback from surveys, complaints, and accreditation reports to highlight systemic issues that need attention.

No doubt using these tools can lead to more efficient administrative decision-making and, in some cases, improved tracking of student outcomes. However, the effectiveness of these tools often depends on the data quality and how well users engage with them.

The existing literature highlights several important gaps that are particularly relevant to Northern Nigeria: There's a need for detailed, region-specific studies on institutional readiness, as most research tends to be either national or focused on single cases. Northern states would greatly benefit from targeted mixed-methods research. We need to conduct longitudinal evaluations of

pilot Artificial Intelligence (AI) projects to assess their long-term effects on administrative outcomes and student success. (The IAFOR Research Archive -). It is also crucial to explore the socio-cultural and governance factors—like leadership attitudes and policy levers—that influence adoption beyond just technical readiness.

AI Analytics and Strategic Decision-Making: While utilizing AI algorithms, the collected data is analyzed to identify patterns, trends, and insights that inform strategic decisions. The analysis yields actionable insights presented through dashboards and reports, highlighting areas for improvement and opportunities for growth. An assessment of AI's effectiveness in implementing public administration programs in Nigerian universities demonstrates its role in automating administrative tasks (Sanni K, *et al*, 2024).

University leadership uses these insights to make informed decisions on policy formulation, resource allocation, and academic planning. A review of AI readiness in higher education institutions in Northern Nigeria addresses the potential of AI in supporting quality assurance processes (Benson R. *et al*, 2024).

AI Automation: Routine administrative tasks are automated using AI, leading to increased operational efficiency and allowing staff to focus on more complex responsibilities. Automation streamlines processes such as admissions, course registrations, and examination grading, reducing errors and processing times. By this, operational efficiency is enhanced in the university system.

AI automation delivers notable efficiencies and analytical capabilities to university administration in North-Central Nigeria. Nevertheless, the journey faces familiar yet addressable challenges: inadequate infrastructure, scattered and low-quality data, evolving regulations (like the Nigeria Data Protection Commission - NDPC), limited human resources, ethical concerns, gaps in procurement and cybersecurity, and cultural resistance. By adopting a practical, step-by-step strategy—such as initiating small, human-in-the-loop pilot projects, emphasising data governance, building capacity, and ensuring vendor diligence—while adhering to NDPC guidelines, we can minimise risks and unlock scalable value.

AI systems continuously monitor policy implementation and compliance, ensuring that university operations align with established standards and regulations. Research on AI's role in educational administration and planning programs in Nigerian tertiary institutions emphasizes its impact on policy implementation and evaluation (Ogumode et al, 2024)

Societal Trends and Institutional Goals

North-Central Nigeria, characterized by its diverse population and socio-cultural nuances, faces challenges in meeting societal needs such as education access, skill acquisition, and employment. Universities in the region aim to produce graduates equipped with relevant skills to address these needs. AI can support this alignment by engaging in personalized learning through AI-driven systems, such as adaptive learning platforms, which cater for individual learning styles, ensuring students acquire the skills necessary for societal integration.

AI-powered online platforms can improve access to education by reducing geographical and infrastructural barriers, promoting inclusivity for underserved communities. They can also

enhance economic development and institutional coordination. The region's economy is shifting from being primarily agriculture-based to more diverse sectors, including technology and services. Universities must prepare graduates for this changing economic landscape.

Other areas of importance are curriculum development. AI analytics provide insights into labour market trends, enabling institutions to align curricula with industry demands. Labour market data from the International Labour Organization (ILO) indicates a 30% increase in technology-driven job opportunities in Nigeria between 2020 and 2023.

AI can enhance research and development capabilities, fostering innovation that can contribute to economic growth. As a result, unemployment can be reduced significantly. It also supports research and broadens the scope of knowledge.

Technological Trends and Institutional Goals

The rise of Artificial Intelligence (AI) and related technologies globally has created a pressing need for digital transformation in universities. Key areas include administrative efficiency, which resulted in AI-powered systems, streamlining administrative processes such as admissions, financial aid, and student management, reducing costs and improving accuracy. Likewise, it aids teaching and learning processes. Intelligent tutoring systems and virtual assistants support educators and students, making learning more interactive and effective. A typical example is Nasarawa State University's integration of AI chatbots to assist students with administrative and academic inquiries resulted in a 40% reduction in staff workload. The University of Ilorin adopted an e-learning platform augmented with AI features, enabling remote learning during the COVID-19 pandemic. This initiative enhanced access and demonstrated the potential for AI in overcoming infrastructural challenges.

AI tools also assist in research collaboration. Nasarawa State University's use of AI tools for research collaboration has improved the quality of academic publications and fostered partnerships with international institutions.

Proposed Framework for Integration

To effectively align institutional goals with changing trends using AI, the following framework is suggested:

1. **Strategic Planning:** Universities should integrate AI into their strategic plans, focusing on areas such as infrastructure, curriculum, and research.
2. **Capacity Building:** Faculty and staff training in AI technologies will ensure effective implementation.
3. **Public-Private Partnerships:** Collaboration with technology firms can provide resources and expertise for AI adoption.
4. **Policy Formulation:** The government and regulatory bodies must establish policies that promote AI adoption while addressing ethical and societal concerns.

This integrated approach enables universities to leverage AI for enhanced governance, ultimately improving educational outcomes and institutional effectiveness.

Challenges of Multi-Predictive Implementation in University Systems in North-Central Nigeria

The implementation of multi-predictive analytics (MPA) in university systems has the potential to enhance administrative processes significantly. However, universities in the North-Central region of Nigeria face several unique challenges that hinder the successful adoption and utilization of these technologies. Below is an in-depth discussion of these challenges with relevant references.

Limited Digital Infrastructure: The foundation of multi-predictive analytics lies in robust digital infrastructure, which includes high-speed internet, reliable power supply, and data storage facilities. However, many universities in North-Central Nigeria face deficits in these critical areas (**Mohammed *et al.*, 2024**). A report by Ajibade *et al.* (2022) highlights that less than 40% of tertiary institutions in the region have access to consistent internet and power, limiting their ability to deploy AI-based tools effectively. These problems affect various activities like teaching, practical activities which is vital (**Sobowale *et al.*, 2024**), administrative efficiency to mention but a few.

Data Scarcity and Quality Issues: Predictive analytics relies on large volumes of accurate and reliable data. Many universities lack well-organized and digitized databases, while existing data are often incomplete, inconsistent, or outdated. Olayemi and Ibrahim (2023) observed that administrative departments in North-Central Nigerian universities often rely on paper-based records, which are prone to errors and loss, complicating data-driven decision-making.

Financial Constraints: The deployment of multi-predictive systems involves significant costs, including software acquisition, hardware upgrades, and staff training. Financial limitations in many universities hinder their ability to invest in these technologies. Universities in the region depend heavily on government funding, which is often insufficient to cover advanced technological initiatives (Eze & Okoro, 2021). Falode and Mohammed (2023) noted that due to challenges like finance and other factors, Nigerian institutions always find it difficult to incorporate modern technology for effectiveness in activities.

Resistance to Change: Many university staff members, particularly older administrators and faculty officers, are resistant to adopting new technologies due to a lack of familiarity or fear of obsolescence. The present-day computing system with AI is strange to many of the old administrators who see it as ethically mystical and unnatural. A study by Adekunle *et al.* (2022), 65% of administrative staff in North-Central Nigerian universities expressed reluctance to adopt AI tools, citing fears of job redundancy and increased workload.

Insufficient Technical Expertise: The implementation and management of multi-predictive systems require specialized skills in data science, machine learning, and AI. However, there is a scarcity of trained personnel in these fields within the region. Adigun and Uche (2020) found that less than 10% of IT staff in universities in North-Central Nigeria have adequate training in advanced data analytics and AI implementation.

Data Privacy and Security Concerns: The use of multi-predictive systems raises concerns about data privacy and security. Universities must ensure compliance with data protection regulations and safeguard sensitive information from breaches, which can be challenging in the Nigerian context. Eniola *et al.* (2021) reported multiple cases of data breaches in Nigerian universities, emphasizing the lack of robust cybersecurity measures.

Cultural and Institutional Barriers: Cultural attitudes and institutional policies can pose barriers to adopting innovative technologies. Universities may lack a culture of innovation or have rigid bureaucratic systems that slow down the adoption process. Onyekachi and Bala (2022) noted that hierarchical decision-making processes in Nigerian universities often delay the approval and implementation of technology projects.

Poor Collaboration among Stakeholders: Successful implementation of MPA requires collaboration between university management, government agencies, and technology providers. However, in North-Central Nigeria, there is often a lack of coordination and synergy among these stakeholders. An investigation by Okoye and Mohammed (2023) revealed that most universities in the region operate in isolation, with minimal engagement with private sector technology firms.

Lack of Policy and Regulatory Framework: There is a significant gap in policies and regulations that govern the use of AI and predictive analytics in the Nigerian educational system. This lack of guidance creates uncertainty and inhibits investment in these technologies. Eze (2021) argued that the absence of a national AI policy for education hampers universities' ability to standardize and optimize multi-predictive implementations.

Inequitable Access to Technology: Within the region, disparities in access to technology exist among urban and rural universities. Institutions in rural areas face greater challenges in adopting predictive analytics due to their location and fewer resources. Oyewole *et al.* (2022) found that rural-based universities in North-Central Nigeria were 50% less likely to adopt new technologies compared to their urban counterparts. Additionally, most institutions do not have access to technology that will bridge the gap between distance and time thus making education affordable and ubiquitous (Mohammed *et al.*, 2025b).

Short-Term Focus of Administrators: University leadership often prioritizes short-term goals over long-term investments in transformative technologies like multi-predictive systems. This shortsightedness can hinder sustained progress. Adebayo (2022) noted that many universities in the region allocate limited funds for technology adoption, focusing instead on immediate infrastructural needs.

The challenges discussed highlight the systemic and contextual factors that need to be addressed to harness the full potential of multi-predictive analytics in North-Central Nigeria's university systems. Overcoming these barriers will require a concerted effort from policymakers, educational institutions, and technology providers.

Ethical and Social Implications

The deployment of predictive analytics may lead to ethical issues such as bias in algorithms and unintended consequences. Universities may struggle to address these challenges due to limited

understanding and frameworks. Adamu and Salami (2023) highlighted cases where predictive algorithms used in admission processes inadvertently favoured certain groups, raising concerns about fairness and equity. The study on AI in public service and governance in Nigeria outlines challenges such as infrastructure deficiencies, funding constraints, skill gaps, and ethical concerns that may impede AI adoption in universities.

To address ethical concerns, Nigerian universities should develop a comprehensive policy framework to responsibly integrate Artificial Intelligence (AI) systems into their administrative functions. This approach aligns with the Nigeria Data Protection Regulation (NDPR, 2019) and the latest conversations around ethical AI governance (Jobin, Ienca, & Vayena, 2019; OECD, 2019). The aim is to ensure that all activities prioritise privacy, fairness, transparency, accountability, security, and inclusion—while adhering to both national and international best practices. The scope of application encompasses all AI-driven administrative systems utilised in universities, whether developed internally or sourced from external vendors. Key areas include admissions and enrolment management, human resources such as recruitment and promotion, financial administration, payroll processing, management of student records and learning analytics, as well as campus security and surveillance systems.

Ethical Principles Guiding AI Adoption

- a) **Privacy and Data Protection:** Adoption of AI systems must comply with NDPR guidelines, ensuring that personal data is collected lawfully, only when necessary, and in a proportionate manner (NITDA, 2019). For all high-risk AI projects, Data Protection Impact Assessments (DPIAs) are mandatory, with findings documented and reviewed before implementation.
- b) **Fairness and Non-Discrimination:** All AI systems should undergo testing for potential biases using disaggregated datasets (like gender, ethnicity, and socio-economic status) to prevent discriminatory outcomes (O’Neil, 2016; Jobin et al., 2019). Any biases identified must be corrected through model retraining or adjustments to the algorithms.
- c) **Transparency and Explainability:** Decisions made by AI systems that impact the rights or opportunities of students or staff must be explained in straightforward, non-technical language. The processes and criteria behind these decisions should be documented and made accessible for review.
- d) **Accountability:** It’s crucial to clearly define who is responsible for the outcomes of AI systems. Even though external vendors might provide AI solutions, the university ultimately holds the responsibility as the data controller (NITDA, 2020).
- e) **Security and Robustness:** AI systems must undergo regular security audits, including penetration testing, to protect against data breaches, adversarial attacks, and other potential vulnerabilities.
- f) **Equity and Digital Inclusion:** When adopting AI, it is important to ensure that no stakeholders are left out due to a lack of digital resources. Accessibility measures, like device loan programs and offline access, should be part of the system design.

Governance Mechanisms: To put this framework into action, Nigerian universities should:

- a) Set up an AI Ethics and Governance Committee to oversee the procurement, deployment, and monitoring of AI systems. This committee already exists in the Federal University of Technology, Minna.
- b) Appoint a Data Protection Officer (DPO) who has the authority to ensure compliance with the NDPR.
- c) Include ethical compliance clauses in all AI procurement contracts, addressing transparency, data ownership, and vendor accountability.

Implementation and Review Strategy: Every university needs to take the following actions:

- a) Immediate Actions: The university needs to appoint or confirm the university Data Protection Officer (DPO), take stock of all AI systems currently in use and start conducting Data Protection Impact Assessments (DPIAs) for high-risk AI projects.
- b) Periodic Review: Every University needs to carry out annual audits of AI ethics and publish a summary for the public that outlines the AI systems in use and their compliance status.
- c) Incident Reporting: Institutions need to create secure channels for reporting errors, breaches, or any signs of bias in AI systems.

Conclusion

The integration of AI into the university educational system in North-Central Nigeria offers significant potential for aligning institutional goals with societal, economic, and technological trends. By addressing challenges and adopting strategic measures, universities can harness AI to drive innovation, inclusivity, and excellence in education and research. Artificial Intelligence (AI) comes with a lot of benefits for academics, administrators, managers, government and people in all walks of life.

However, there are challenges to the holistic adoption of AI. These challenges are surmountable if adherence to the standard rules of ethics is well guarded with sincerity. It is not an exaggeration to say that AI is highly disruptive and transformational, as observed by Joe (2023). To a large extent, heavy reliance on AI can disrupt the young generation of natural brainstorming. Consequently, instead of man remaining as the primary source of knowledge, reasoning, observation and innovation, these functions may shift to artificial intelligence. Nevertheless, its positive uses make it indispensable. To maintain balance, teachers, engineers, health workers and administrators should be able to draw lines between the use of intellect and artificial intelligence. Truly, Artificial Intelligence (AI) has come to stay, and we have to embrace it as a useful tool in university administration, but the naturalness in humans must not be lost.

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MANAGEMENT AND SECURITY OF LIBRARY RESOURCES IN NIGER STATE COLLEGE OF NURSING SCIENCES

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Abstract

The aim of this study is to investigate management and security of library resources in Niger State College of Nursing Sciences library. To achieved this objective, three research questions were formulated. The population of the study covered 62 library staff of Niger State college of nursing sciences which was manageable. Therefore, total enumeration was done and the whole population was adopted for the study. Questionnaire were used as the main research instrument administered to cover the population. Descriptive statistic was used in the analysis of data (frequency count and percentage). The findings showed that library staff of the college were aware of the information securities. The study recommendations were advanced to enhance the securities for both the library users and its managers.

Keywords: Management, Security, Library Resources

Introduction

Library play a fundamental role in the academic institutions that the resources and services they offer create opportunities that support the parent institution's teaching, learning and research activities (white, 2012). Similarly. Libraries are institutions set up to cater for the educational, cultural, research, recreational and information needs of its users. Libraries have the have the main objectives of being entrusted with the selection, acquisition, organization, storage and dissemination of information to their patrons (Matthew, 2004).

Management is the coordination and administration of task to achieved a goal in an organization. In the context of library management involves a lot of items like planning, making decisions concerning the goals of the library, organizing and assembling. Libraries need to also monitor the various performances of the library and even leading by way of putting efforts to encourage high performance.

Library security is one of the major threats faced by library professionals and library staff to preserve and conserve library resources secured. Library security is a simple technique for effective method of protecting library resources. Gupta & Madhusudham (2018). observed that library security is a broad term and can be defined as the arrangements provided for safe and secure facilities for library staff, library resources, equipment and library users. The security of library materials are of utmost importance to the librarians and information specialist to avoid unauthorized access to information materials available in the library (Parker, 2002).

Ameen, K. & Haidar, S. J. (2018). observed that to avoid unauthorized access to library materials, library provide adequate security measures that can protect the information resources available in the library. Library resources are information materials that enable the library to fulfill its goal of

meeting the information needs of its users. Management and information professionals must devise strategies which will enable them to manage information needs of its users (Ajegbomogun, 2014).

Niger State College of Nursing Sciences

The college was established in 2016, inheriting three schools each with already existing conventional academic/medical library. The schools were established with the mandates to train middle manpower nurses/midwives with a view of supportive roles to doctors in the quest to save lives, care of sick people including pregnant women and aiding to safe birth deliveries, NMCN (1982). School of Midwifery Minna Campus, School of Nursing Bida Campus and School of Nursing/Midwifery Kontagora campus.

The school of midwifery Minna Library was established the same year with the school in 1982 with critical desire need of manpower to run and maintain general hospitals, clinics and health centers in the state especially for pregnant/nursing mothers and children. Presently the library has a total volume of 1,0960 resource materials including books, journals, periodicals and student's projects. Also, with 7 academic staff, 12 non-academic staff, totaling 19 personnels

The school of nursing Bida library was established the same period with school in 1976, shortly before the creation of Niger State which was curved out from the defunct North Western State. The aim/objectives even then, was to meet up with challenges of producing professionally, trained personals who will cater for health care deliveries at all levels of the communities. The library has resources materials of 9,561 including text *books* journals, encyclopedias and periodicals, including daily subscription of daily trust and new Nigeria newspapers. The library has 18 personnel of which 8 are academic and 10 are non-academic.

The school of nursing/midwifery Kontagora, established in 2014 has an academic library with materials voluming 6,800 including textbooks, journals, encyclopaedia and periodicals with a staff weight of 17 personnel, of which 5 are academic librarians and 12 nonacademic librarians.

Literature Review

Library security challenges are regarded as acts committed by users of the library against library resources. These acts could be theft, mutilation, defacement of the collection. According to Jato (2005), scandalous behaviors such as theft and mutilation, hiding library materials, refusal to return overdue borrowed materials, drinking and eating in the library, vandalism and defacement of library collections, arson, negligence to library policies as well as various disaster such as fire and flood caused by human factors, among others have become a common occurrence in academic libraries and if this is not checked, it would lead to serious drought of information materials in the library. Most academic libraries in developing countries, including Nigeria, lack security measures. This encourages library patrons to perform such acts. Abubakar, B.A., & Abdullahi, S. (2020) stated that the delinquent readership in selected urban libraries in Nigeria revealed that every library has a delinquent client problem and that there is no direct correlation between the type of library and the extent of the problem. As such, the problem seems to be universal, academic libraries have been faced with varying degrees of criminal behaviors in the use of their resources especially materials, and to some extent manpower. The extent of this problem varies from one library to another. In some cases, the dimension of the problem is so restricted that it seems non-existent, in some others the dimension is so immense that it calls for serious concern.

Ugah (2007) in one of his studies in Michael Okpara University of Agriculture, Umudike Nigeria considers library security threat as formidable obstacles to information access and use. Such acts, he states, are serious problems that can result in user dissatisfaction. He identified major security issues in libraries to include theft and mutilation, vandalism, damage and disaster, over borrowing or delinquent borrowers, and purposely displacing arrangement of materials. Literature on collection security have shown that security often happen where there is security and crime challenges in academic libraries in Nigeria when the library premises are left unsecured. Over the years, many factors have been militating against theft, hiding of book, vandalism unauthorized borrowing and mutilation as risks management in academic libraries, these ranges from unqualified security personnel to user delinquency such as bad attitudes towards library collections. Theft and mutilation could be perpetrated at any hour of the day (Idris, Hassan & Abdul-Qadir 2013).

Oder (2004) maintains that security measures such as supervision, patrolling, and surveillance are lacking in libraries and keys are kept unsecured. He agrees that security personnel inefficiency is also a big avenue to library crime, especially in academic libraries. Wrong borrowing of library materials is a threat to the effective use of resources, and to avoid this library should create policies to ensure library resources are used effectively. Nancy, (2016) on the use of electronic security to combat book theft and the experiences involved in their installation in the United States. Nancy further stressed that the adoption of video surveillance and closed-circuit television (CCTV) systems serve as a way to monitor vandalism in the library. The system, this can also be used to monitor and record evidence on clientele and employee. video surveillance and closed-circuit television (CCTV) systems serve as a way to monitor and record security, deter crime and ensure safety. The system can also be used to monitor and record evidence on clientele and employee misconduct. That video surveillance should only be employed to provide a safe and secure facility for library employees, library resources and equipment, and library patrons. Ramana (2010) contributed that closed-circuit television (CCTV) used in the libraries can enhance the ability to control the book theft and tearing off the pages from the books and magazines. In the same vein. The libraries also get the most benefit from adopting such measures in controlling unauthorized access.

Nielson (2002) described library security management to be ‘simply too bad a state of affairs. Destructive habits of some users such as theft, mutilation and hiding of information materials pose a great problem to other users who are most often prevented from having access to library collections. Arising from these unwholesome practices, the library staff also experience difficulties providing quality services while the library management runs into financial mess of replacing lost or damaged collections (Popoola

2003). According to Ajegbomogun(2014) stated that theft and mutilation of books and non-books is a common phenomenon in Nigerian University libraries and if not checked will create a serious threat to library’ collections and their preservation acknowledged that, some library users display disruptive or criminal behaviors within the library surroundings and this can cause security problems in the library. The issue of information resources security is of growing concern to academic libraries and librarians. As a result, there are studies on problems concerning library security in academic libraries.

Statement of the Problem

security in today's libraries is not an easily achievable task since the causes of crime are diverse (Mansfield 2009). In Niger State College of Nursing Sciences there are various causes involved in the loss of books and other library resources. These causes are staff and patron problem, technical and administrative problems, e.t.c. There are many illegal practices in Niger State College of Nursing Sciences such as theft, mutilation of books, hiding of books, misplacement, unauthorized borrowing, non-returned of books, vandalisms of library properties and disruptive behavior by the users e.t.c. These are more rampant in the college libraries; the libraries have to adopt and implement suitable security measures to improve security in the library resources. It is for these reasons that the researcher conducted the study to look into the management and security of information resources in Niger State College of Nursing Sciences library.

Objectives of the Study

1. To identify the type of security available in Niger State College of Nursing Sciences library.
2. To find out the causes of security in Niger State College of Nursing Sciences library.
3. To identify the challenges of security in Niger State College of Nursing Sciences library

Research Questions

1. Types of security available in Niger State College of Nursing Sciences library.
2. Causes of insecurity in Niger State College of Nursing Sciences library.
3. Challenges of security encounter in Niger State College of Nursing Sciences library.

Research Methodology

The study adopts survey research method. The population of the study comprised of 62 staff of college of nursing sciences library Niger State, therefore total enumeration was used for the study because the population is manageable. The study used questionnaire as instrument for data collection in each of the studied library. 62 copies of questionnaires were distributed to the respondents in their various units and returned for data analysis. Descriptive statistics was used in the analysis of data (frequency count & percentages).

Presentation and Analysis of Data

Table 1: Type of security available in Niger State College of Nursing Sciences library.

Items	Agreed Frequency (%)	Disagreed Frequency (%)	Total	%
Security Guard	62(100%)	-	62	100
Registration of Users	62(100%)	-	62	100
Locks and Key system	62(100%)	-	62	100
Clearance Procedures	62(100%)	-	62	100
ID Card	62(100%)	-	62	100
Signature of Users	62(100%)	-	62	100
Fire Extinguisher	62(100%)		62	100

Closed-Circuit Television (CCTV)	-	62(100%)	62	100

Table 1. Indicate that the entire respondents 62(100%) were aware that security guard, registration of users, lock and key system, clearance procedures, signature of users ID card and fire extinguishers are available in the college libraries. This implies that librarians should be extra security mindful of the management of library resources, to ensure their own safety and the safety of the resources. 62(100%) of the responded disagreed that closed-circuit television is not available in the college libraries environment. Ramana (2010) contributed that closed-circuit television (CCTV) used in the libraries can enhance the ability to control the book theft, mutilation of books and magazines. They serve as a way to monitor vandalism in the library.

Table 2: Causes of Insecurity in Niger State College of Nursing Sciences Library

Items	Agreed Frequency (%)	Disagreed Frequency (%)	Total	%
Poor Orientation to Library Users	-	62(100%)	62	100
Insufficient Library Resources	-	62(100%)	62	100
High Cost of Books	62(100%)	-	62	100
Inadequate Security Measures	62(100%)	-	62	100
Inadequate Library Staff	62(100%)	-	62	100
Financial Constraint	62(100%)	-	62	100

Table 2. Indicate that the respondents 62(100%) disagreed with poor orientation to library users and Insufficient library resources respectively as a cause of insecurity in the college's libraries, due to the fact that all new admitted student nurses and midwives usually took the general course use of library. On the issue of insufficient library resources, the college management try as much as possible to make available information resources relevant to users need. The table 2 indicate that the causes of insecurity were many with 62(100%) respondents have agreed that high cost of books, inadequate security measures, inadequate library staff and financial constraint are all causes of library insecurity in Niger State college of nursing sciences library. This is in line with Ajegbomogun (2014) on his research acknowledged that, some library users display disruptive or criminal behaviors within the library surroundings and this can cause security problems in the library.

Table 3: Challenges of Security encounter in Niger State College of Nursing Sciences

Items	Agreed Frequency(%)	Disagreed Frequency(%)	Total	%
Mutilation of Books	62(100%)	-	62	100
Book Theft	62(100%)	-	62	100
Eating in the Library	62(100%)	-	62	100
Unauthorized Borrowing	62(100%)	-	62	100
Vandalism	62(100%)	-	62	100
Hiding of Books	62(100%)	-	62	100
Non returned of Books	62(100%)	-	62	100
Noise Making	62(100%)	-	62	100

Table 3. indicate that all the respondents 62(100%) of Niger State College of Nursing Sciences Libraries encountered the following challenges, book theft, mutilation of books, hiding of books, eating in the library unauthorized borrowing, non-returned of books, vandalisms and noise making. This goes with the findings conducted by Momodu (2002) on the delinquent readership in selected urban libraries in Nigeria revealed that every library has a delinquent client problem and that there is no direct correlation between the type of library and the extent of the problem. As such, the problem seems to be universal. In another development (Idris, H. & AbdulQadir, 2013). On their research stated that many factors have been militating against theft, hiding of book, vandalism unauthorized borrowing and mutilation risks management in academic libraries, these ranges from unqualified security personnel to users' negligence towards library resources. It could be perpetrated at any hour of the day.

Conclusion

The study concluded that library staff of Niger State College of Nursing Sciences Libraries were aware of different types of security available in the libraries. Henceforth. The library management needs to make a drastic move towards improving necessary security measures in the libraries. The causes and challenges of security in the library should be address to ensure better safety and security to the precious resources in the libraries.

Recommendations

Based on the findings of this study, the following recommendations are hereby made:

1. Library Staff should always monitor the activities of users, especially around the reading and the shelving areas of the library
2. The college management should install Close Circuit Television (CCTV) security system in strategic places in the library so as to monitor the activities of both staff and users in and around the library environment.
3. Competent security guards should be at the main entrance to help detect the library resources stolen from users.

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A PARADIGM SHIFT TOWARDS ADAPTIVE INTELLIGENCE (AI) FOR SUSTAINABLE AGRICULTURE IN NIGERIA: A CRITICAL ANALYSIS

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Abstract

This position paper argues for a critical strategic pivot. We posit that achieving genuine food security and economic sustainability necessitates a leapfrog to Adaptive Intelligence (AI). A paradigm centered on dynamic, learning systems, such as Reinforcement Learning (RL), which optimize resource use through interaction with a volatile environment rather than static, pre-defined rules. Grounding our argument in the Theory of Planned Behavior and Sustainable Intensification, we construct a conceptual framework for Adaptive Intelligence that integrates data, adaptive algorithms, and socio-economic integration. We critically analyze how this approach directly addresses the limitations of existing technology adoption models and technocentric critiques of intensification by prioritizing affordability, robustness, and contextual learning. The paper contends that RL based systems offer a theoretically sounder and more practical path for Nigeria, moving beyond mere precision towards true resource resilience. We conclude with a series of urgent policy recommendations aimed at fostering national research, pilot programs, and ethical guidelines to catalyze this essential transition, ultimately positioning Adaptive Intelligence as the key to empowering Nigerian farmers and building a sustainable agricultural future.

Keywords: *Adaptive Intelligence, Reinforcement Learning, Sustainable Intensification, Smallholder Agriculture, Digital Agriculture*

Introduction

Nigeria's pursuit of food security and economic sustainability is central to its national development agenda. Policies such as the Agricultural Promotion Policy (2016-2020) have explicitly championed the adoption of technology and precision agriculture (PA) to bridge the significant yield gap faced by the country's millions of smallholder farmers (FMARD, 2016). However, the prevailing approach has largely involved the transfer of high-cost, capital-intensive precision technologies designed for Western large-scale monocultures into a context defined by smallholdings, resource constraints, and heterogeneous agro-ecological conditions (Bello-Bravo & Lutomia, 2021). This misfit has resulted in low adoption rates and limited impact, failing to catalyze the promised transformation. This position paper argues that the current trajectory is insufficient. We contend that a fundamental paradigm shift is necessary: from static Precision Agriculture to dynamic Adaptive Intelligence (AI). We define Adaptive Intelligence as systems, particularly those leveraging Reinforcement Learning (RL), that learn optimal decisions through continuous interaction with a complex and volatile environment. This paper posits that national policy and research investment must be reoriented towards developing these context-aware, affordable, and learning-driven systems to genuinely empower Nigerian farmers and achieve sustainable agricultural outcomes.

The Promise and Pitfall of Precision Agriculture in Nigeria Empirical studies highlight the potential benefits of PA in Nigeria including yield improvements and resource savings. Research by Ogunmodede et al. (2020) demonstrated that sensor-based irrigation could reduce water use by up to 30% in Northern Nigerian wheat fields. However, the literature also consistently identifies critical barriers: the high capital cost of IoT sensors, the complexity of operation for farmers with low digital literacy, and inadequate maintenance infrastructure (Kamara *et al.*, 2021). These studies conclude that without significant adaptation, imported PA technologies will remain confined to large-scale commercial farms, excluding the smallholders who form the backbone of Nigerian food production.

The Emergence of AI and Machine Learning in Agriculture Globally, AI application in agriculture is burgeoning. Van Klompenburg *et al.* (2020) conducted a systematic review confirming the efficacy of machine learning (ML), particularly supervised learning, for crop yield prediction. However, their research also exposed a critical gap: these models require massive, labeled historical datasets for training—a resource notoriously scarce for Nigerian smallholdings due to a lack of digital record-keeping (Ayinde et al., 2020). This empirical finding underscores the need for AI approaches that are less dependent on big data. A Nascent but Potent Solution Empirical evidence from other regions suggests RL is uniquely suited for dynamic decision-making problems. Gao et al. (2022) successfully deployed an RL agent for greenhouse irrigation in China, which learned optimal policies that outperformed traditional timers, adapting to daily variations in solar radiation and temperature. This demonstrates RL's core strength: its ability to learn from interaction and simulation, thus bypassing the need for extensive historical datasets. This makes it theoretically ideal for data-scarce environments like Nigeria.

Conceptual Theories and Their Critiques

Theory of Planned Behavior (TPB)

Application: TPB (Ajzen, 1991) explains technology adoption through attitudes, subjective norms, and perceived behavioral control. High-cost PA negatively impacts perceived behavioral control (farmers feel they cannot afford or operate it).

Critique: TPB is often micro-centric, underestimating macro-level structural barriers like poor rural internet and electricity. An Adaptive Intelligence system must be designed to function within these constraints (e.g., using sparse data and SMS alerts) to genuinely improve perceived control.

Sustainable Intensification Theory

Application: This theory advocates for increasing yields without adverse environmental impact or

Critique: Critics argue it can promote a technocratic, top-down approach that marginalizes indigenous knowledge and local context. Our Position: Adaptive Intelligence can integrate this critique. The "reward function" in an RL system can be engineered to balance yield with sustainability goals (water conservation, cost reduction). It doesn't impose a single solution but learns the best strategy for a specific context, potentially harmonizing scientific and local knowledge.

Diffusion of Innovations Theory

Application: This theory explains how new technologies spread through a social system. PA has a high "complexity" and low "trialability" for Nigerian farmers, slowing its diffusion (Rogers, 2003).

Critique: The theory can be passive, describing diffusion rather than proactively designing for it. An Adaptive Intelligence model delivered as a simple, subscription-based "service" (e.g., via SMS) would significantly lower the complexity and cost barriers, actively accelerating its own diffusion and adoption.

Methodology: A Proposed Pathway

Implementing Adaptive Intelligence requires a phased, research-driven approach:

1. **Problem Formulation & Environment Modeling:** Collaborate with agronomists to create a simulated "digital twin" of a Nigerian maize farm. This model would encapsulate soil dynamics, crop growth, and local weather patterns.
2. **Algorithm Selection and Training:** Employ a model-free RL algorithm like a Deep Q-Network (DQN). The agent's state space would include soil moisture, nutrient levels, and weather forecasts. Its actions would be irrigation and fertilizer levels. The reward function would be: $R = (\text{Estimated Yield}) - (\text{Water Cost}) - (\text{Fertilizer Cost})$.
3. **Validation:** Initially validate the AI's policy against expert agronomists' recommendations in simulation. Subsequently, conduct controlled pilot studies with partner farming cooperatives, using affordable sensors for minimal ground-truthing.
4. **Delivery Mechanism:** Develop a low-tech user interface. The AI's daily decisions could be communicated to farmers via USSD codes or SMS messages (e.g., "Dial *123# to receive today's irrigation advice"), ensuring accessibility.

Conclusion and Recommendations

The empirical evidence and theoretical analysis presented confirm that continuing on the current path of importing unsuitable PA technologies will yield diminishing returns. Adaptive Intelligence, built on frameworks like Reinforcement Learning, represents a more theoretically sound, empirically viable, and contextually appropriate paradigm for Nigeria. It aligns with adoption theories by reducing complexity and cost, and it addresses the critiques of intensification by being adaptive and customizable.

Recommendations:

1. **Policy Shift:** NABDA and FMAFS should officially recognize and fund research into "Adaptive Intelligence for Smallholder Systems" as a strategic priority.
2. **Pilot Funding:** TETFund and other grant agencies should earmark funds for interdisciplinary research teams (computer scientists, agronomists, economists) to build and test RL models for key Nigerian value chains (e.g., maize, cassava).
3. **Regulatory Foresight:** A multi-stakeholder taskforce should be established to develop preliminary guidelines for ethical AI in agriculture, focusing on data privacy, algorithmic transparency, and fairness.

4. Public-Private Partnerships: Encourage partnerships where tech companies develop the algorithms, telecom providers offer the data infrastructure, and agro-dealers act as distributors for the "intelligence-as-a-service" model.

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EFFECT OF ENTREPRENEURIAL SKILLS ON PERFORMANCE OF POULTRY FARMERS IN NIGERIA

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Abstract

The study reviewed literature on effect of entrepreneurial skills on performance of poultry farmers in Nigeria. Agriculture remains a cornerstone of Nigeria's economy, with poultry farming emerging as one of the most commercialized and profitable sub-sectors. Despite its potential to generate income, create employment, and enhance food security, the sector faces persistent challenges, including high feed costs, disease outbreaks, limited access to finance, and inadequate management skills. This study examined the effect of entrepreneurial skills on the performance of poultry farmers in Nigeria. The study highlighted those entrepreneurial skills such as financial literacy, innovation, risk management, proactiveness, resilience, and networking are critical determinants of poultry farmers' productivity, profitability, and sustainability. Researches reviewed in the study revealed that farmers with strong entrepreneurial competencies were more likely to adopt modern technologies, access profitable markets, manage resources effectively, and achieve both financial and non-financial performance outcomes. The study underscores the importance of entrepreneurship as a driver of agricultural transformation and rural development. The study recommends among other that government agencies, universities, and agricultural extension services should design and implement regular training programmes that focus on financial literacy, record-keeping, marketing and innovations for poultry farmers.

Keywords: Entrepreneurial, Entrepreneurial Skills, Performance, Poultry Farmers

Introduction

Globally, agriculture plays a vital role in economic development, poverty alleviation, and food security. Among the many subsectors of agriculture, poultry farming stands out due to its rapid return on investment, minimal land requirements, and ability to generate employment, especially in rural and peri-urban areas (FAO, 2020). The poultry industry supplies affordable and high-quality animal protein in the form of meat and eggs, thereby addressing nutritional needs while contributing to national income and exports in several countries. Despite its potential, the performance of poultry farming enterprises is often hindered by challenges such as inadequate access to finance, poor management practices, fluctuating market prices, disease outbreaks, and lack of innovation. These problems are particularly prevalent among small- and medium-scale poultry farmers, many of whom lack the necessary entrepreneurial skills to run their farms as viable business ventures. Entrepreneurial skills are increasingly recognised as essential for success in agricultural enterprises. These skills include opportunity identification, innovation, risk management, business planning, marketing, and financial literacy. When poultry farmers possess strong entrepreneurial capabilities, they are more likely to adopt new technologies, respond effectively to market changes, and make informed decisions that improve productivity and profitability.

Concept of poultry farming

Agriculture continues to serve as a cornerstone of Nigeria's economy, employing over 35% of the labour force and contributing significantly to food security and rural development (National Bureau of Statistics (NBS, [2021](#)). Among the various agricultural enterprises, poultry farming has emerged as a prominent sub-sector due to its short production cycle, high demand for poultry products, and relatively low capital requirements. Poultry farming in Nigeria has contributed to income generation and employment and has also helped in addressing the nutritional needs of the growing population through the provision of affordable sources of animal protein (FAO, [2019](#)). Poultry is a collective name given to a group of birds reared or hunted for useful purposes. They can also be referred to as domesticated birds kept for egg or meat production which include chicken, ducks, geese, turkeys, pigeon, guinea fowl, quail among others. The poultry sub-sector is the most commercialised (capitalised) of all the sub-sectors of the Nigerian agriculture (Salau *et al.*, 2017). The poultry sector constitute more than 57% of the total livestock production in Nigeria and many people have gone into poultry production either producing egg or meat or both (Nwarieji *et al.*, 2017). Otieno *et al.* (2017) added that poultry production contributes 30% of the agricultural GDP.

Poultry production involves the breeding, tending and/or raising of poultry to produce eggs and meat. In Nigeria, poultry production systems can generally be differentiated into two groups, namely, subsistent and commercial. The commercial system can be further classified into small, medium and large scale with modern technology. Small, medium and large scale vary in size from 10000-20,000, 20,001-50,000 and >50,000 birds, respectively. According to Salau *et al.* (2017) small scale poultry production is made up of farms having less than 1,000 birds while medium scale farms are those having between 1,000 and less than 5,000 birds. In the commercial production system exotic and high producing birds are kept under care. In the subsistence production, birds are mostly of indigenous breeds that roam the homestead and scavenge for feed freely (Adeyemo and Onikoyi, 2012). The types of poultry that are commonly reared in Nigeria are chickens, ducks, guinea fowls, turkeys, pigeons and more recently ostriches. In Nigeria, poultry farmers benefit from structured training, institutional support, and a robust supply chain, which enhances their entrepreneurial development. However, in many developing nations, farmers operate in informal sectors with limited access to capacity-building programs or formal education, limiting their ability to grow and sustain their businesses (Nugent, [2018](#)).

The adoption of poultry farming is a practice that has both psychological and sociological dimensions. Despite the potential of poultry farming in Nigeria, the sector is still plagued by numerous challenges such as high feed costs, poor disease management, limited access to credit, inadequate veterinary services, and weak market linkages (Akinola *et al.*, [2020](#)). These problems are often exacerbated by the limited entrepreneurial capacity of many poultry farmers, most of whom engage in farming at a subsistence or semi-commercial level. As a result, productivity and profitability remain low, limiting the growth of the sector.

Concept of Entrepreneurial skills

Entrepreneurial activities are substantially different depending on the type of organisation that is being started. Entrepreneurship ranges in scale from solo projects (even involving the entrepreneur only part-time) to major undertakings creating man) job opportunities. Recently, the term entrepreneurship has been extended to include elements not related necessarily to business

formation activity such as conceptualizations of entrepreneurship as a specific mind set. The term entrepreneurship is derived from a French word “entrepreneur” meaning one who undertakes tasks in a production process (Salau *et al.*, 2017). Entrepreneur is a person who organises and operates a business venture and assumes much of the associated risk (Otieno *et al.*, 2017). Entrepreneurship is a key factor in promoting economic development, innovation, competitiveness and job creation. Also, Nwarieji *et al.* (2017) submitted that entrepreneurship is a process of bringing together creative and innovative ideas, combining them with management and organization skills in order to combine people, money, and resources to meet an identified need and thereby create wealth.

Amusa and Dumbiri (2010) defined entrepreneurial skills as the required capacities to perceive business opportunities, take advantage of the scarce resources, control and coordinate available human and material resources for success in any production enterprise. It could also be defined in terms of specific functions which the entrepreneur performs or in terms of characteristics or activities generally associated with the entrepreneur (Okoli, 2013). Entrepreneurship is the tendency of an organisation to engage in activities designed to identify and capitalize successfully on opportunities, to launch new venture by entering new or established markets with new or existing goods or services’ (Nmadu and Ndace, 2018). The perception of entrepreneurship involves generating and funding innovative ideas in order to make profit (Victor *et al.*, 2020). While entrepreneurship comprises of a person (the entrepreneur) and his or her activities and tasks, the entrepreneurial tasks and activities focus on starting, developing and continuing a profitable business. Invariably, an entrepreneur is someone who produces for the market. In view of this, Victor *et al.* (2020) viewed entrepreneurship as comprising of an innovator, independent thinker and a creative person who is capable of transforming opportunities into new ideas while at the same time managing and measuring risk. The entrepreneurial skills include the following: ability to identify customer needs, ethnical opportunities and market opportunities. A successful entrepreneur may find (or create) an opportunity and then develop skills to capitalise on the opportunity.

Entrepreneurial skills have been increasingly recognised as a key factor in enhancing the performance of agribusinesses, including poultry enterprises. Skills such as opportunity recognition, financial literacy, innovation, risk-taking, and record-keeping are essential for effective farm management and sustainable business growth. Entrepreneurial skills refer to the capabilities and mindset required to identify business opportunities, mobilise resources, take calculated risks, and sustain profitable ventures in dynamic environments. Entrepreneurship skills are associated with competence in the process of opportunity identification (and/or creation), the ability to capitalise on identified opportunities and a range of skills associated with developing and implementing business plans to enable such opportunities to be realised. Entrepreneurial skills are defined as the capacities required by poultry farmers to envision business opportunities in the poultry industry and explore, allocate, coordinate and efficiently manage the input resources for optimum productivity (Salau *et al.*, 2017). Entrepreneurial skill is the ability of an individual to exploit an idea and create an enterprise not only for personal gain but also for social and developmental gain (Nwarieji *et al.*, 2017). Entrepreneurial skills are the ability to manipulate input resources efficiently within particular enterprise to achieve the production goals. There are a number of qualities and skills poultry farmers need to have. Nwarieji *et al.* (2017) highlighted farm management skills in poultry production enterprises which include accountancy and financial

management skills, marketing skills, information skills, decision making skills, risk oriented skills, communicative skills and technical skills.

Dimensions of Entrepreneurial skills

Micheltmore and Rowley (2013) identified six main entrepreneurial skills which include the following: identification and definition of a viable market niche; development of products or services appropriate to the firm's market niche /product innovations; idea generation; environmental scanning; recognising and envisioning taking advantage of opportunities, and formulating strategies for taking advantage of opportunities. The dimensions of entrepreneurship skills are discussed thus:

Networking skills: These are vital entrepreneurial skills that enables poultry farmers to tap into wider value chains from input procurement to market access. A study by Ramos-Rodriguez et al. (2024) found that entrepreneurs deeply embedded in social networks excel at spotting opportunities and mobilising resources. For poultry farmers, active engagement in cooperatives or producer groups enables bulk input purchases, negating intermediaries and lowering transport costs. Moreover, networking through associations establishes trust among buyers and financiers, promoting favourable credit arrangements and market contracts. The collaboration of poultry farmers through peer networks help them to regularly share best practices in disease control, feed formulation and farm management. Beyond financial gains, such networks foster mutual support helping farmers manage crises like disease outbreaks or regulatory shifts. Those embedded in robust peer and institutional networks have greater access to real-time market intelligence, resulting in improved farm performance and sustainability.

Financial literacy: This forms the backbone of entrepreneurial competence in poultry farming by empowering farmers to manage costs, optimise investments, and control risk. Many poultry producers adopted rudimentary financial controls resulting in missed opportunities and revenue leakages. Effective financial practices including capital budgeting, cost-benefit analysis, and loan assessment were shown to significantly improve farm profitability, yet remain underutilised. Farmers with financial acumen could accurately forecast and buffer these expenses thereby reducing shocks and enhancing resilience. Financial literacy transcends technical knowledge embedding farmers in intentional, data-driven management, essential for long-term success.

Creativity and innovation: These are paramount in enhancing the sustainable performance of poultry farms. Planting non-conventional feed sources like black soldier fly larvae (BSFL) instead of sole reliance on expensive commercial options can significantly cut costs while boosting bird health. Innovative strategies ranging from cost-saving feed alternatives to diversifying income streams through incubation services create durable competitive advantages. Innovative marketing and business models also differentiate poultry enterprises. Examples include farmhouse egg delivery services and branded poultry meat targeting niche segments. Adekun (2023) noted that small-scale Nigerian poultry farmers who innovate in marketing and operational techniques record higher returns, as innovation enables them to tap into underserved demand and offset industry fluctuations. Vertical integration trend producers combining feed production and poultry enterprises in one business ecosystem illustrates cost reduction, improved supply chain control, and economies of scale. Thus, creativity is a strategic imperative for modern poultry entrepreneurs.

Resilience and Risk Management: This entails capacity to absorb disruptions such as disease outbreaks, feed-price surges, and policy shocks and recover quickly. A 2021 Nigerian study in Southwestern Nigeria found that farms implementing vaccination protocols, biosecurity measures, and emergency-response systems maintained significantly more stable production during crises compared to less-prepared farms (Ogunyemi et al., 2021). Risk management extends to financial and operational planning. During feed shortages or disease events, farmers with strong social networks shared resources and knowledge minimising losses.

Risk Taking: This result from a willingness to commit significant resources anmay be borrow heavily in order to venture into the unknown tendencies (Nmadu and Ndace, 2018). The possibility to take risks can be assessed by considering whether people are bold or cautious. Whether they require high levels of certainty before taking or allowing action and whether they tend to follow tried and true paths. Darmadji (2015) asserted that an entrepreneur need to show the attitude of an independent, vibrant, ever willing to take risk in order to achieve certain objective.

Proactiveness: This is an act in anticipation of future opportunities and likely threats/problems. A proactive entrepreneur shapes the environment and changes the competitive landscape. They are always forward thinkers who are fast to act and are leaders rather than followers. Similarly, some entrepreneurs are more likely to be proactive, to shape and create their environments, than other who are passive, they casually adapt to situations in which they find themselves. Entrepreneurs who are proactive encourage and create space for individuals and teams to exercise their ability. They can improve the quality of life of their families and communities, and sustain a healthy economy and environment. The sustainability of a farm enterprise depends on the innovativeness and proactive measures that guides the decision of entrepreneurs in carrying out their activities.

Performance in entrepreneurial skills

The performance of an organisation usually comprises the actual results when measured against its goals and objectives (Otieno *et al.*, 2017). It involves measuring the results of a particular process or procedure, then modifying the process to increase the results, increase efficiency, or increase the effectiveness of the process. The main purpose of organisational performance is to increase its effectiveness and efficiency in delivering goods and services. Performance in entrepreneurial skills reflects the extent to which individuals effectively apply business-related competencies to achieve tangible outcomes such as profitability, growth, innovation, and sustainability. In poultry farming, entrepreneurial performance encompasses strategic decision-making, market responsiveness, operational efficiency, and income generation. Entrepreneurs who demonstrate higher proficiency in entrepreneurial skills tend to record better business performance metrics, including increased productivity, customer retention, and business expansion (Akanbi and Oludele, 2012). Several empirical studies have highlighted the positive link between entrepreneurial skill performance and enterprise success. For instance, Abiola and Ajayi (2014) found that entrepreneurial skills in financial management, marketing, and innovation significantly influenced the profitability of small-scale poultry businesses in Ogun State, Nigeria. Similarly, Akinbami and Akintola (2020) revealed that poultry farmers in Oyo State who possessed higher levels of entrepreneurial competence achieved superior performance in areas such as product quality, customer satisfaction, and business continuity. Furthermore, entrepreneurial performance is often enhanced through continuous training, access to market information, and exposure to modern business practices. Salami and Aremu (2022) emphasised that the entrepreneurial

performance of youth-led agribusinesses in Southwest Nigeria improved significantly after targeted interventions in skills training and mentorship. This aligns with global evidence from the FAO (2020), which reported that performance in agribusiness ventures improves when farmers are empowered with entrepreneurial and managerial skills. Thus, enhancing performance in entrepreneurial skills is critical not only for individual business success but also for achieving broader socio-economic objectives such as employment creation, food security, poverty alleviation, and rural development.

Dimensions of Performance in Entrepreneurial Skills

Performance in entrepreneurial skills is commonly assessed through two primary dimensions, namely: financial and non-financial performance. These dimensions provide a comprehensive evaluation of an entrepreneur's success and business sustainability. While financial performance focuses on quantifiable economic outcomes, such as profits and return on investment, non-financial performance evaluates qualitative factors like customer satisfaction, innovation, and social impact (Chimucheka, 2014; Wiklund and Shepherd, 2003). According to Neneh (2016), both dimensions are essential, especially in small and medium-scale agribusinesses, as they reflect the ability to maintain operational viability and adapt in competitive markets. In agricultural entrepreneurship, where externalities such as climate, access to capital, and market unpredictability are prevalent, the dual consideration of financial and non-financial indicators provides a balanced view of entrepreneurial success and resilience.

Financial performance: This refers to the monetary outcomes of entrepreneurial activities and remains a key indicator of business health and viability. It includes profit margins, return on assets, sales growth, cost management, and overall profitability (Agyapong et al., 2011). In poultry farming, financial indicators such as feed cost efficiency, egg or meat sales revenue, and investment return are critical in assessing the impact of entrepreneurial competencies. According to Abiola and Ajayi (2014), poultry farmers in Ogun State who demonstrated strong financial management skills recorded higher gross margins and profitability. Financial performance, therefore, is not only a measure of success but also a driver of expansion and long-term sustainability in agribusiness ventures.

Non-financial performance: This refers to outcomes that are not directly measurable in monetary terms, but are crucial to business sustainability and stakeholder engagement. These include customer loyalty, product quality, innovation, brand reputation, and community impact (Fatoki, 2014; Neely et al., 2002). For poultry entrepreneurs, maintaining hygiene standards, ensuring animal welfare, and responding to customer preferences are important non-financial aspects that influence market competitiveness. A study by Akinbami and Akintola (2020) found that farmers who invested in customer relationships and quality control experienced increased patronage and market trust, even in price-volatile seasons. Non-financial performance helps build resilience, social capital, and long-term brand equity especially vital for small-scale entrepreneurs in rural or developing economies.

Effect of entrepreneurial skills on performance of poultry farmers

Entrepreneurial skills are essential for ensuring the sustainability, productivity, and competitiveness of businesses, particularly in small and medium-scale enterprises such as poultry farming. These skills including financial literacy, innovation, strategic planning, risk management,

and networking enable entrepreneurs to navigate market uncertainties, optimise resource use, and respond quickly to changes in consumer demand. Adekunle et al. (2020) emphasised that entrepreneurial competencies are paramount in transforming subsistence farming into viable agribusiness models. The relevance of entrepreneurial skills is also highlighted in capacity building and rural economic development. According to Nwibo and Okorie (2013), farmers equipped with entrepreneurial skills are more likely to adopt improved production technologies, engage in value addition, and access profitable markets, thereby improving their income and livelihood. Furthermore, Ojo and Salau (2018) found that Nigerian poultry farmers who demonstrated high levels of entrepreneurial orientation such as innovation, proactiveness, and risk-taking achieved significantly better economic outcomes compared to their less entrepreneurial counterparts. Entrepreneurial skills also enhance record-keeping, budgeting, customer relationship management, and decision-making, which are all critical to the long-term success of poultry ventures (Olawoye & Olaniyan, 2021). Entrepreneurial skills not only empower individuals to start and manage agribusinesses effectively but also contribute to broader development outcomes such as employment generation, food security, and rural transformation. Governments and development agencies have thus recognised the need for entrepreneurship education, extension services, and training programs that integrate these competencies into agricultural practice, especially in the poultry sector.

In poultry farming, the application of entrepreneur skills has become increasingly vital due to rising market competition, fluctuating input prices, and growing consumer demand for quality products. Poultry farmers around the world are becoming more market oriented as they have learned to take calculated risks to open or create new markets for their products. As global food systems evolve, the need for farmers to function not just as producers but as entrepreneurs has gained prominence. Entrepreneurial capacity is a supplementary asset and a core requirement for survival and success in agri-based enterprises. This shift necessitates a deeper understanding and adoption of entrepreneurial competencies tailored to the specific demands and uncertainties of the poultry sector. Entrepreneurial skills in poultry farming encompass a multidimensional set of competencies such as innovation, risk-taking, networking, financial literacy, and resilience each crucial to transforming traditional poultry operations into viable agribusinesses. Farmers with strong entrepreneurial skills are more likely to adopt modern production techniques, respond to market demands, and access finance and input services, which in turn improve their overall performance. Recent empirical evidence highlighted how entrepreneurial orientation particularly innovativeness and risk propensity directly contribute to improved farm outcomes. For instance, in Kwara State, Adekun (2023) conducted a survey of 206 small-scale poultry farmers and found a statistically significant positive relationship between innovativeness, risk-taking behaviour, and increased sales and profitability. Similarly, in Nasarawa State, Salau et al. (2019) reported that 70% of the farmers demonstrated entrepreneurial skill, with extension contact, training, and farm size emerging as significant predictors. Acquisition of the needed entrepreneurship skills is therefore critical for the growth and sustainability of the poultry in Nigeria. These findings established that technical knowledge in poultry farming must be complemented with entrepreneurial competence to ensure sustainable and competitive performance in volatile market environments. Entrepreneurial skill performance influences strategic thinking, opportunity identification, and the ability to innovate in resource-constrained environments, particularly in agribusiness sectors like poultry farming (Abiola & Ajayi, 2014; Akinbami and Akintola, 2020). Evidence from Salami and Aremu (2022) study showed that poultry farmers who receive

entrepreneurship training experience measurable improvements in productivity, customer satisfaction, and business sustainability. Salau et al. (2017) study revealed that there is a positive relationship between entrepreneurship skills and level of business success. Furthermore, the FAO (2020) emphasised that improved entrepreneurial performance among youth and small-scale farmers directly contributes to rural transformation and resilience. Therefore, promoting entrepreneurship education, access to finance, mentorship, and market linkages is crucial for equipping farmers with the skills needed to compete effectively and contribute meaningfully to national economic growth and food systems development.

Poultry farmers need a broad array of entrepreneurial skills to succeed in today's market. They must possess essential entrepreneurial skills that will increase their efficiency and effectiveness in knowledge delivery and management of resources in the poultry farm environment. Entrepreneurial skills in poultry production are a powerful means of addressing relatively low production and enhance innovation in poultry enterprise. It provides new inputs, expertise, and services needed for production; expands employment and entrepreneurial opportunities in rural and urban areas and can contribute to the growth of small-scale enterprises. They must possess basic skills necessary to enable them function effectively and thereby increase the quantity and quality of their products. Developing skills in breeding techniques will increase the productivity of eggs and meat and reduce mortality of chicks and growers. Entrepreneurial skills in breeding, husbandry, and management are needed to increase the efficiency in poultry production, which will lead to lower production costs (Nwarieji *et al.*, 2017). He also noted that, the nutrition of poultry has to do with feeds and feeding which include all the processes whereby the feed nutrients and oxygen are presented to be utilised by the cells of the birds and the resulted waste product eliminated. The costs of medication and vaccination and of feed constitute substantial input costs in production (Esiobu, 2014). Poultry disease is the departure of the birds from the state of good health in which all the body physiological parameters are not performing in perfect normal condition (Nwarieji *et al.*, 2017). Pest and parasites affect poultry adversely, they retard growth and affects feed efficiency and utilisation, leaving the birds stunted and emaciated.

Conclusion

The study concluded that entrepreneurial skills play a pivotal role in enhancing the performance of poultry farmers in Nigeria. Farmers equipped with competencies in financial management, risk-taking, innovation, and networking recorded better productivity, profitability, and market competitiveness compared to their less-skilled counterparts. Entrepreneurial capacity not only improves farm-level outcomes but also contributes to broader socio-economic objectives such as food security, job creation, and poverty reduction. Thus, technical expertise in poultry production must be complemented with entrepreneurial competence to ensure sustainable growth and resilience in the face of market volatility and production risks. Furthermore, the study highlighted that improving entrepreneurial performance enhances both financial indicators such as profitability, cost efficiency, and return on investment, as well as non-financial indicators like customer satisfaction, innovation, and community impact. Poultry farmers who continuously develop their entrepreneurial skills stand a better chance of thriving in Nigeria's competitive agricultural sector.

Recommendations

Based on this review, the following recommendations were made:

- i. Government agencies, universities, and agricultural extension services should design and implement regular training programmes that focus on financial literacy, record-keeping, marketing and innovation for poultry farmers.
- ii. Policymakers should improve poultry farmers' access to affordable credit facilities through cooperative thrift and loan societies, agricultural banks, and microfinance institutions.
- iii. Poultry farmers should be encouraged to join cooperatives and producer associations to enhance collective bargaining, bulk purchasing of inputs, and better market access.
- iv. Poultry farmers should be supported to adopt innovative practices such as alternative feed production, vertical integration, and modern disease management systems to reduce costs and increase efficiency.
- v. Experienced poultry entrepreneurs and agribusiness experts should mentor small and medium-scale farmers to foster knowledge transfer, resilience, and improved risk management.
- vi. Poultry farmer's association should organise training on local feed formulation for their members to reduce the over dependent on commercial feeds in order to cut production costs.

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PREDICTION OF NITROGEN CONTENT IN MAIZE LEAVES BASED ON MACHINE LEARNING APPROACH

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Abstract

Nitrogen is the most important nutrient needed in appropriate quantity by maize in order to maximize expected yield, to be able to quantify the minimum amount required will help minimize resource usage and improve yield. Traditional manual methods of determining nitrogen availability in plant such as chemical test, visual inspection and chlorophyll meter reading are time consuming, inaccurate, costly and cannot handle the complex relationship that exists between factors that determine the nitrogen availability in a plant tissue. In this study, deep machine learning algorithm and pretrained model were utilized in predicting nitrogen levels in maize plant. This research employed Convolutional layers to extract feature from maize leaf image to meticulously train the Convolutional Neural Network (CNN) model achieving an accuracy of 99.00%. Other pre-trained algorithm such as Visual Geometry Group 16 (VGG16), VGG19, and Residual Network18 (ResNet18) were also trained achieving an accuracy of 92.75%, 82.00% and 76.18% respectively.

Keywords: Maize, Nitrogen, Convolutional Neural Network (CNN), Visual Geometry Group 16 (VGG 16), Machine learning.

Introduction

Optimizing crop yield is essential for meeting the increasing demand for food while maintaining environmental sustainability (FAO, 2021). Maize cereal is an important food staple needed by human and animal needs fertile soil for it to perform to the required expected capacity (Muntean *et al.*, 2022). In Africa Nigeria is the second largest producer of maize crop after South Africa with Ethiopia at the third-place position in terms of harvest. Together, these countries (South Africa, Nigeria and Ethiopia) accounted for about 39% of the total harvest of the cereals in the continent (African Plant Nutrition Institute, APNI. and CSIR - Savanna Agricultural Research Institute, 2022). The application of unrationalized nitrogen fertilizer on the farm lands in order to improve yield leads to negative impact on the environment promoting leaching, denitrification (Peng *et al.*, 2021). Surface runoff of soil nutrients accounts for more than half of nitrogen lost in maize farming (Pooja *et al.*, 2020). Local farmers have to use large amount of nitrogen fertilizer in order to maximize their yield (Syaiful *et al.*, 2023), determining the minimum amount of nitrogen fertilization needed by a plant to achieve optimal yield is a serious issue for promoting best farming practice that increase yield and crop profitability, great concern by environmentalist to protect underground water from nitrate contamination (Rajput *et al.*, 2023). Nitrogen is the key macro nutrient crucial to maize growth, good yield and needed in appropriate quantity for the production of proteins, starches, sugar in the kernel and promotes the plant resistance to negative effect of abiotic stress (Aziiba *et al.*, 2019). The deficiency of this nutrient shows up first in older leaves turning to pale or yellowish green forming an inverted “V” or spear shaped decoration starting from the tip of the leaf extending inwards (Jones, 2021). Laboratory test on maize leaves and soil testing is some of the method of diagnosing the available nitrogen content in the plants, however

these methods are tedious, destructive, costly and time consuming. In order to have a solution to this issue, researchers have promoted the use of nondestructive tools to the plants and ecosystem. Deep Machine learning tools like CNN algorithm can be leveraged to assess the nitrogen content in plants. This algorithm has an encouraging good accuracy in classifying objects using its kernels to extract features (Bangsa et al., 2023). The remaining sections of this paper are organized as follows: section 2 gives an account of the existing related literature to the subject matter, while the methodology and methods employed were accounted for by section 3, section 4 discusses the results obtained, and finally the conclusion section.

Related works

This section highlights some of the similar research work done, the machine learning approaches employed and the result obtained.

To show the importance of nitrogen to maize plant as proposed by a study to determine the nitrogen deficiency by (Adesanya & Yinka-Banjo, 2022) in corn plant using pre-trained Single Shot Detector (SSD) MobileNetV2 algorithm to construct a nitrogen deficiency detection model using sample images of maize leaf as dataset for training, the developed model has an accuracy of 81 percent. Patel *et al.*, (2025) conducted a research to determine the level of zinc, potassium, nitrogen and phosphorus in maize plant by analyzing different leaves image samples, features of the leaves were extracted using Gray-Level Co-occurrence Matrix (GLCM) while classification was achieved with Support Vector Machine (SVM) and Gradient Boosting (GB), their developed ensemble model for detecting nitrogen has an accuracy of 0.8068, F1-score of 0.8050. Sun *et al.*, (2024) propose a system that leverages machine learning algorithm to predict nitrogen content in maize using machine vision and Convolutional Neural Network (CNN), the fully connected layers of the CNN were reconstructed to form a regression task that will output numerical value of nitrogen in quantity, the resulting model achieved an accuracy of 93%. Corn aerial multispectral image data captured by UAV were employed by (Bagheri, 2024) to train a mathematical model for predicting nitrogen and chlorophyll level, the model was evaluated to have an accuracy of 98 percent. Weizhong *et al.*, (2023) address a problem of classifying the nitrogen level in maize into three categories namely low nitrogen, medium nitrogen and high nitrogen using extracted features from the leaf images, five machine learning models (Support Vector Machines, K-Nearest Neighbor, Decision Tree, Linear Regression and Random Forest) were trained. Linear Regression was the best classifier having an accuracy of 96.8%. Wu *et al.*, (2023) develop a model for measuring nitrogen content in maize leaves based on fusion images and spectral features, Gray Level Co-occurrence Matrix (GLCM) was adopted for extracting leaves features and SVR and PLSR algorithm were used to formulate the prediction model. The PLSR model has the most accurate result with RMSE of 0.967. Cheng *et al.*, (2024) suggest performance evaluation of model developed using collected spectral image data and nitrogen content of maize leaves in Beijing District to form nine nitrogen estimation models SPA (Successful Projection Algorithm), LASSO (Least Absolute Shrinkage and Selection Operator Algorithm), EN (Elastic Net Algorithm), MLR (Multiple Linear Regression), MSR (Multiple Stepwise Regression) and PLSR. PLSR model was such a success that was observed to have the most accurate result with RMSE=0.96 and $R^2=0.92$. Ghazal *et al.*, (2024) established a model to classify nitrogen deficiency in maize crop into three stress classes namely stressed, semi stressed and nonstressed using RGB image data obtained from the field to train ResNet50, EfficientNetB0, InceptionV3 and DenseNet121. It was reported that EfficientNetB0 was the optimal classifier with an accuracy of 97%.

Methodology

Deep learning algorithms, Convolutional Neural Network (CNN) and its other pre-trained variant ResNet18, VGG16, and VGG19 were leveraged for model developments and for comparison purposes in order to identify the optimum classifier. CNN algorithm in this study as the basal model after fine tuning is a type of deep learning algorithm designed for processing photographic details like images; the algorithm performs very well in identifying features in photographic data giving it the ability to perform well in image details recognition task. This research utilizes an image dataset of maize leaf photos taken with a camera and annotated by a plant leaf morphologist. Data preprocessing such as data annotation, augmentation, resizing and rescaling of the image sample were performed before training the models.

Table 1 displays Analysis of the used maize leaf photographic image Dataset comprising of 5,793 images. For the training dataset the low nitrogen level leaves has 1407 samples, Low2 has 1203 samples, moderate has 1400 samples and normal nitrogen level has 1380 samples. The testing Dataset also contains the Low nitrogen level leaves of 101 samples, Low2 has 100 samples, moderate has 101 samples while normal nitrogen level contains 101 samples respectively. Samples of the image dataset are shown in figure 1.

Table 1. Analysis of Used Dataset

Dataset	Low	Low 2	Moderate	Normal
Training Image	1407	1203	1400	1380
Test Image	101	100	102	100

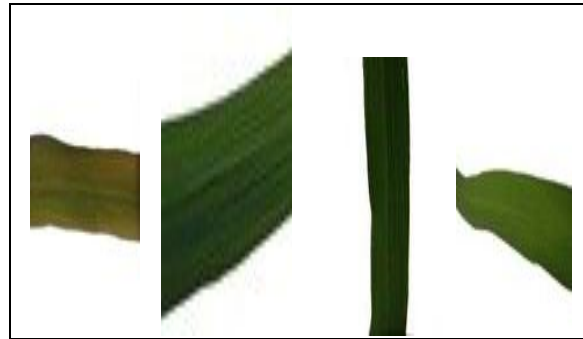


Figure 1. Maize leaf Sample image dataset taken with a camera

Table 2: System Algorithms

<i>Input: t</i> <i>Output: return n_l</i> <i>Parameters: maize leaf image (t), preprocess F_{xn}, resizing (r_e), rescaling (r_s), augmentation (a_n), nitrogen level (n_l), Prediction (p_d).</i>
1. <i>Input t</i> 2. <i>For all t preprocess F_{xn}</i> 3. <i>$t \leftarrow r_e, r_s, a_n$</i> 4. <i>$M \leftarrow (p_d)$</i> 5. <i>Return n_l</i>

Table 2 depicted the system algorithm with Sample of maize leaf (t) which nitrogen is to be predicted as input to the system, resizing, rescaling and augmentation preprocessing task

performed on the input image and finally the CNN model will be employed to predict (p_d) the level of nitrogen content of the leaf.

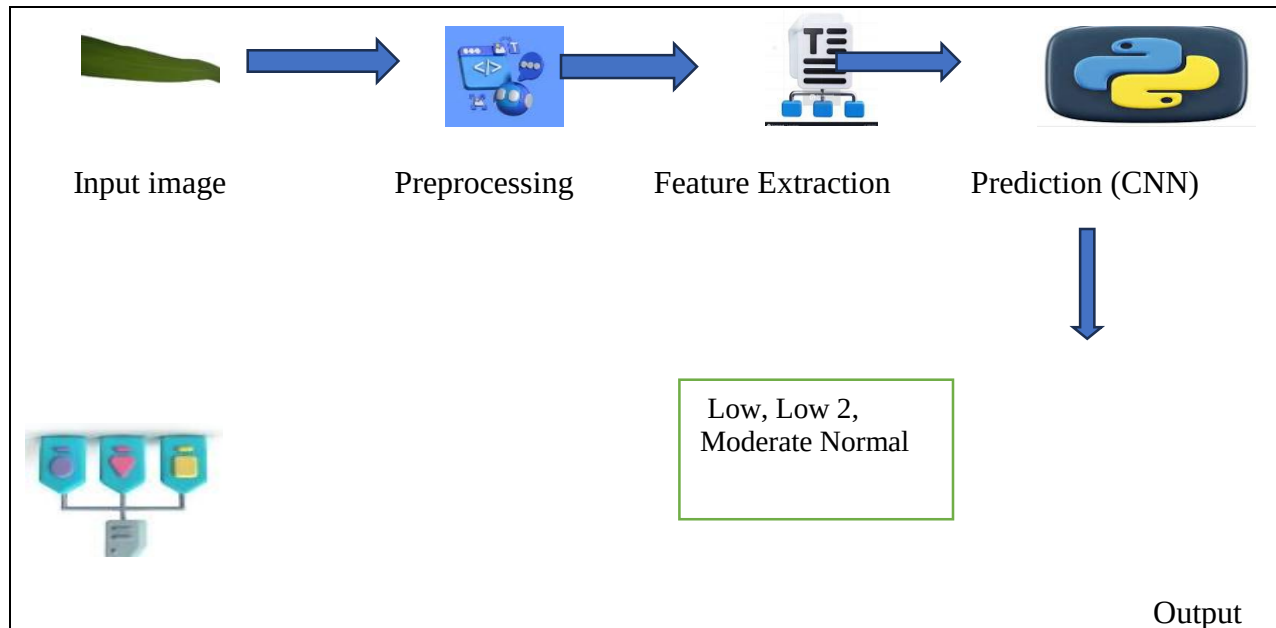


Figure 2. The Conceptual Framework of the Proposed System

Figure 2 depicted workflow on how the developed system operate, a sample of maize leaf image in which its nitrogen level is to be predicted will be inputted into the system, pre-processing task such as reseizing, augmentation, will be done before extraction of features by the convolutional layers and classification using CNN model will output the nitrogen level as either Low, Low 2, Moderate and Normal.

Results and Discussion

This section presents and discusses the results obtained from the four trained models in relation to Accuracy, F1-score, Precision, the explanation of the models Confusion Matrix parameters such as True Positive (TP) (True: because samples are correctly classified and positive because samples belong to the class under consideration), True Negative (TN) (True: because sample were correctly classified and Negative: because samples were not classified into the class under consideration), False Positive (FP) (False: because samples are incorrectly classified and False: because sample were classified into the class under consideration) and False Negative (FN) (

False: sample are incorrectly classified and Negative: samples not classified into the class under consideration).

Table 3 Depicted the summary of the results obtained by ResNet18 model the Resnate18 confusion matrix in figure 3

<u>Classes/VGG16</u>	<u>TP</u>	<u>TN</u>	<u>FP</u>	<u>FN</u>
Low	94	301	1	7
Low 2	100	297	6	0
Moderate	87	290	11	15
Normal	90	289	14	10

Table 4: Summary result for VGG16 model

<u>Classes/Resnate18</u>	<u>TP</u>	<u>TN</u>	<u>FP</u>	<u>FN</u>
Low	78	302	0	23
Low 2	100	210	93	0
Moderate	37	301	0	65
Normal	92	300	3	8

Table 3. ResNet18 Model result summary

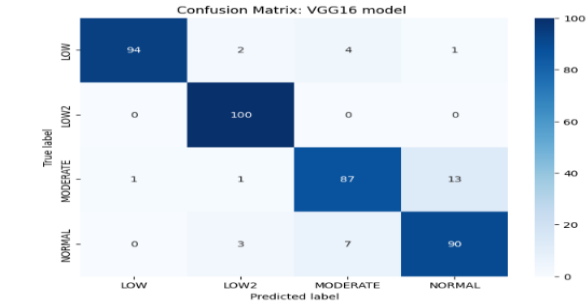


Figure 4. VGG16 Confusion Matrix

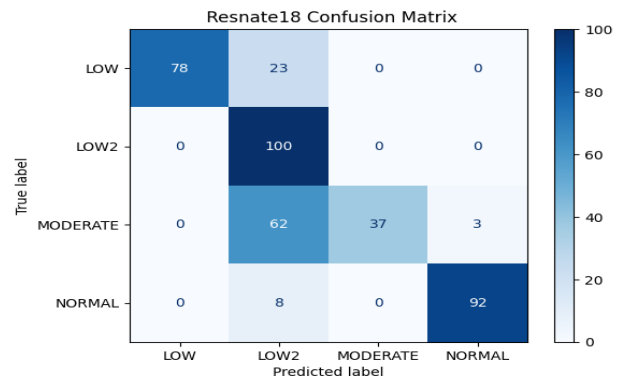


Figure 3: ResNet18 Confusion Matrix

The result of the ResNet18 model obtained from its confusion matrix in figure 3 is summarize in table 3. Showing Nitrogen level Leaf test dataset sample Low has TP of 78, TN of 302, FP of 0, and FN of 23. Low 2 achieve TP of 100, TN of 210, FP of 93 and FN of 0. Moderate has TP of 37, TN of 301, FP of 0, and FN of 65 while normal achieve 92, 300, 3, 8 for TP, TN, FP and FN respectively.

Table 4 Depicted the summary of the results obtained by VGG16 model extracted from its confusion matrix shown in figure 4. Nitrogen level Leaf test sample Low has TP of 94, TN of 301, FP of 1 while FN is 7. Low 2 has TP of 100, TN of 297, FP of 6 and FN of 0, Moderate produce 87, 290, 11, 15 of TP, TN, FP and FN. While Normal achieve 90, 289, 14, 10 for TP, TN, FP, FN respectively.

Table 5 Depicted the summary of the results obtained by CNN model extracted from CNN model confusion matrix in Figure 5. CNN model was able to classify the various classes of the test dataset into Low with TP of 99 TN of 302, FP of 0, and FN of 2. Low 2 produce 100, 291, 12 and 0 for TP, TN, FP and FN respectively. Moderate TP is 90, TN is 299, FP is 2, and FN of 12 while normal test leaf sample has 100, 303, 0 and 0 for it TP, TN, FP, FN respectively.

Classes (CNN)	TP	TN	FP	FN
Low	99	302	0	2
Low 2	100	291	12	0
Moderate	90	299	2	12
Normal	100	303	0	0

Table 5: Summary result for CNN model

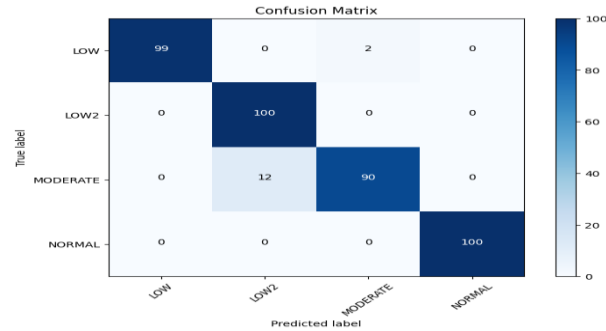


Figure 5. CNN Confusion Matrix

Table 6 Depicted the summary of the results obtained by VGG19 model extracted from its VGG19 confusion matrix displayed in Figure 6.

The result of the VGG19 model obtained from its confusion matrix is depicted in table 6, indicating Nitrogen level test Leaf sample low has 82, 295, 7, 19 as its TP, TN, FP, FN values. Low 2 produce 100, 254, 13, 36 for its TP, TN, FP, and FN respectively. Moderate has TP of 66 TN of 289, FP of 31, FN of 17, while Normal has TP, TN, FP, FN of 82, 281, 22, 18 respectively.

Classes (VGG19)	TP	TN	FP	FN
Low	82	295	7	19
Low 2	100	254	13	36
Moderate	66	289	31	17
Normal	82	281	22	18

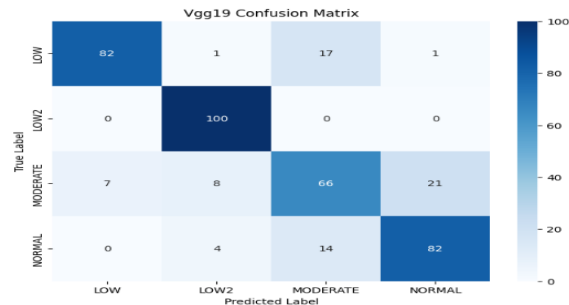


Figure 6. VGG19 Confusion Matrix

Table 6: Summary result for VGG19 model

From the analysis of the result obtained by each of the models, Resnet18 has an accuracy of 76.18, VGG16 achieved an accuracy of 92.00, CNN obtained the most accuracy of 99.00 while VGG19 has an accuracy of 82.00.

Conclusion

This paper presents a study to develop machine learning models that classify nitrogen level in maize plant into four classes, custom-built CNN model architecture was designed and three other pretrained models were employed and trained specifically on the acquired dataset giving us the ability for comparison. The performance of the develop models were verified using, Accuracy

measure, F1-score, and Precision. After each model evaluation from the result obtained, it was discovered that the four models' performance were different with the CNN model having the best performance with a test accuracy of 99.00%, F1-score of 96.55% and Precision of 96.75%. Based on the outcome of this study, this develop model will be helpful to agronomics for the determination of nitrogen content in maize plant.

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A REVIEW ON THE DEVELOPMENT OF ARTIFICIAL INTELLIGENCE COUNSELLING CHATBOT FOR MITIGATING MALADJUSTED BEHAVIOUR AMONG SECONDARY SCHOOL STUDENTS IN NIGER STATE, NIGERIA

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Abstract

The paper presents a review on the development of Artificial Intelligence Counselling Chatbot for mitigating maladjustment behaviours among Secondary School Students in North central, Nigeria. Artificial intelligence counselling Chatbot (AICC) are computer programs design to stimulate human speech through text or voice interactions. It can be described as artificially constructed software using natural language as input and output to communicate with human. The primary purpose of a Chatbot, which can participate in written or spoken conversation, is to stimulate intelligent human speech to the need of learners. Thus, the students can have opportunity to experience a real like Chat process. Various names are given to Chatbot such as AI assistant, smart virtual assistants, digital assistants, speech agents, virtual agents, achievement bot. creative bot candy, harmony, amazebot, helper bot, the botfather, lovely bot, smiles bot happiness, jokester bot good vibes bot joy bot amusing bot hearty bot joyous, helpy, happy bot chuck and Russell. This review summaries relevant research on meaning and overview guidance and counselling, maladjusted behaviours, and artificial intelligence counselling Chatbot. The paper also underscores the future of artificial intelligence technologies in education and benefit of artificial intelligence in education which consist of access to personalized learning, and improvement of student's performance were also identified in the study. The paper concluded by advocating for further researches on the use of artificial intelligence counselling Chatbot (AICC) for teaching guidance and counselling in secondary schools. Government organizations, agencies and non-governmental organization should fund more researches on the use of artificial intelligence counselling Chatbot in Nigeria School, procure technologies that can enhance the use of AICC for teaching and learning in schools. Schools' authorities and management should provide enabling environment for counsellors, teachers and students for effectively use of AICC for their teaching activities more seminars conference and workshops should be organized for educational stakeholders to meet up with global technologies.

Keywords: Artificial Intelligence Counselling Chatbot, maladjusted behaviours, Mitigating

Introduction

With Development of modern technology in the 21st century, educators and learners of all stripes now have access to an abundance of electronic gadgets and innovative applications, through Technology which has created opportunities for rich and creative ways to address problems in education and offer answers to the growing demands on learning resources like Artificial Intelligence which can be use in addressing maladjusted behaviour.

Artificial Intelligence (AI) powered devices are gaining popularity, from self-driving cars to customer service with virtual assistants like chatbot (Nayak *et al.*, 2023). The development of AI is going beyond what people can imagine, chatbot is increasingly asserting its important role in many areas of life. Artificial Intelligence plays an essential role in developing a chatbot that can learn how to understand humans and make a decision. The most important components of the artificial intelligence that can make a successful chatbot are natural language processing (NLP) and Machine Learning (ML) (Khan & Rabbani, 2021; Bird *et al.*, 2021). Chatbots are being researched and developed at a rapid pace. The application of chatbots in career guidance and admissions consulting is increasingly attracting the attention of secondary schools (Su *et al.*, 2020). Furthermore, the construction and completion of chatbot tools based on information technology enrollment data, and career counselling data contribute to the effective support for enrollment counselling at secondary schools throughout the country.

Counselling chatbots are defined as conversational tools that represents a counsellor in providing students with instant services and responses. According to Su *et al.* (2020). a counselling chatbots is a tool that combines artificial intelligence (AI) and natural language processing or other technology, which enables it to interact to a certain level of conversation with a human interlocutor through text or voice.

Counseling chatbots have been gaining popularity in a variety of industries because of their ability to mimic human conversation, which results in automated services and, consequently, reduced human labor. A counselling chatbot structure for guidance and counselling students would need to be able to take input from the student, such as questions, concerns, or personal information. This might be through text input, audio input, or a combination of both. The possibilities offered by counselling chatbot as an educational tool encourages students to use this technology.

Counselling chatbot can be used to encourage student engagement and participation in class discussions or activities, by asking questions or providing feedback in a non-judgmental and interactive way without or with little support of their school counsellors. Students are encouraged by their school counsellors to take responsibility for learning and develop self-regulation skills by having autonomous conversations with the counseling chatbot (Ait Baha *et al.*, 2023).

Overview of Guidance and Counselling

Guidance and counseling are crucial tools in the educational line for guiding children away from the harmful notions in a child induced by his/her peers or environment to a positive perspective. Hence, every school needs a guidance counselor to help modify the children's future through counseling therapy. There is high regard and admiration given to the school guidance counselor by the students. Counselors are expected to become friends with schoolchildren, listen to their complaints and shortcomings, and provide them advise to mould them into the appropriate path for their future endeavours (Nkechi *et al.*, 2016). There are various guidance services that the school guidance counsellor is expected to follow to help solve student's educational problems, these services are the basic elements of the guidance and counselling programs; they are the official schedules or steps the school guidance counsellor takes to make guidance and counselling operational and available to students in addressing maladjusted behaviour (Lasisi and Ibrahim, 2024)

Overview of Maladjusted Behaviour

Maladjusted behaviour refers to actions or attitudes that deviate from societal norms and hinder an individual's ability to function effectively in social or academic settings. These behaviours often stem from emotional or psychological distress and can manifest as aggression, anxiety, phobia, or inferiority complexes. Types of maladjusted behaviours include externalizing behaviours (e.g., aggression, defiance) and internalizing behaviours (e.g., anxiety, social withdrawal) (Muris et al., 2018). Such behaviours are common among adolescents due to the psychological and social changes associated with this developmental stage. Left unaddressed, maladjusted behaviours can lead to academic underachievement, strained relationships, and mental health issues.

Secondary school Students' lives are marked by a range of issues, including aggressiveness, anxiety, phobia and inferiority complex. Some students respond effectively to these challenges, while others do not, putting them at risk for many different mental issues, evolving hostile behavior toward their professors, coworkers, and environment (Wei, 2022). Aggression is a multidimensional notion that comes from a complicated interplay between factors that are biological, psychological, social, and cultural (Azasu *et al.*, 2024). The authors further noted that aggression can be described as deliberate behaviors designed to harm another person. Physical aggressiveness, verbal aggression, anger, and threat are the four components of aggression.

Overview of Artificial Intelligence Counseling Chatbot

Artificial intelligence (AI) refers to the ability of a computer to exhibit human-like intelligence. An AI chatbot is a natural-language processing system that uses artificial intelligence technology to independently engage in conversation with humans. Chatbots are software programs designed to interact like humans. They are distinguished by their use of machine learning and deep learning, which enable them to process data more efficiently and improve the quality of their responses through repeated learning (Wilson and Marasoiu, 2022). Digital intervention platforms are taking various forms, such as mobile applications, telehealth, and web-based interventions. AI chatbots represent the latest innovation being employed in health interventions (Kim, 2024).

Future of Artificial Intelligence Technologies in Education

As technological change accelerates, there is an urgent need for supporting education systems in managing new opportunities and risks. If managed well, technology particularly artificial intelligence (AI) offers a unique opportunity to help education systems enable Education 4.0 teaching and learning approach that focuses on providing learners with the abilities, skills, attitudes and values fit for the future (World Economic Forum, 2024). UNESCO (2024) mandate calls inherently for a human-centred approach to AI. It aims to shift the conversation to include AI's role in addressing current inequalities regarding access to knowledge, research and the diversity of cultural expressions and to ensure AI does not widen the technological divides within and between countries. Furthermore, UNESCO has developed within the framework of the Beijing Consensus a publication aimed at fostering the readiness of education policy-makers in artificial intelligence. This publication, *Artificial Intelligence and Education: Guidance for Policy-makers*, will be of interest to practitioners and professionals in the policy-making and education communities.

Benefits of artificial intelligence technologies in education

For the past decade, chatbots have been increasingly integrated into various facets of education, including assessments, admissions, consultations, and campus life. Using AI-driven virtual assistants may improve efficiency and create leaner workflows. By automating routine tasks such as course registration and student inquiries, staff can attend to more complex and pressing issues. Chatbots can potentially enhance student engagement and retention by providing personalised recommendations, proactive reminders, and timely interventions.

Conclusion

The use of artificial intelligence counselling Chatbot (AICC) will enable learners solve their emotional problems, maintaining their good mental health, facilitating their behavioural changes, enhancing their decision making and enhancing their personal effectiveness with the aid of the Chatbot. Hence, need for further researches on the development of AICC for teaching guidance and counselling among secondary students. Government organisations, agencies and Non-Governmental Organisations should fund more researches in AICC in Nigeria, procure technologies that can enhance the use of AICC for teaching and learning in schools. School authorities and management should provide enabling environment for teachers and students to effectively use AICC for their teaching and learning activities. More conferences, seminars and workshops should be organised for Nigerian educational stakeholders to meet up with the global technologies. Research institutes in Nigeria should consider the designing and development of AICC for educational purposes to improve education among guidance and counselling students in Nigeria.

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IMPACT OF PHET SIMULATION AND YOUTUBE VIDEO PLATFORM ON ACHIEVEMENT AND ATTITUDE OF PHYSICS SENIOR SECONDARY SCHOOL STUDENTS IN MINNA METROPOLIS NIGER STATE, NIGERIA.

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Abstract

This study investigated the impact of PhET interactive simulations and YouTube educational videos on the academic achievement and learning attitude of senior secondary school physics students. A quasi-experimental design was employed with a population of 1000 students from which a stratified random sample of 200 students was selected. The sample was divided into three groups: Group A (PhET Simulation), Group B (YouTube Videos), and Group C (Control - Traditional Teaching). Pre-test and post-test scores were collected using a validated Achievement Test and Attitudinal Scale. Data were analyzed using SPSS Version 25 with descriptive and inferential statistics. The result revealed a statistically significant difference in the post-test achievement scores of students exposed to PhET simulation ($M = 82.15$, $SD = 5.42$) and YouTube videos ($M = 78.32$, $SD = 6.07$) compared to the control group ($M = 67.88$, $SD = 7.01$), with a p -value < 0.05 . Attitudinal responses also favored the intervention groups, with a grand mean of 3.72 indicating positive perception. The study concludes that multimedia tools like PhET and YouTube significantly enhance students' performance and attitude toward physics learning. It recommends integrating these platforms into regular instructional practice.

Keywords: *PhET simulation, YouTube videos, Physics achievement, Student attitude, educational technology, SPSS, Quasi-experimental design*

Introduction

Physics is a foundational science that enables students to understand the fundamental laws governing the natural world. However, it remains one of the most challenging subjects in secondary school curricula, often associated with abstract concepts, mathematical rigor, and a lack of practical experience. As a result, students frequently exhibit low achievement and negative attitudes toward physics.

Traditional methods of teaching physics, primarily reliant on textbook-based instruction and chalk-and-talk approaches have been found to be insufficient in meeting the diverse learning needs of students in the digital age. The integration of technology in education offers opportunities to bridge this gap, particularly through the use of interactive tools and multimedia platforms that can simplify complex concepts.

Among such technologies are PhET Simulations, developed by the University of Colorado Boulder, which provide interactive, research-based science and mathematics simulations. These tools allow students to manipulate variables and visualize outcomes in a virtual lab setting.

Similarly, YouTube, as the world's largest video-sharing platform, hosts a plethora of educational content, including animated physics tutorials, real-life demonstrations, and expert lectures.

This study explores the impact of these two digital platforms-PhET Simulations and YouTube Videos-on students' academic performance and attitudes toward physics. By comparing these tools to traditional instructional methods, the study aims to provide empirical evidence for educators and policymakers seeking to enhance science education through technology integration.

Statement of the problem

Despite the recognized importance of physics in technological and scientific advancement, students' achievement in the subject remains unsatisfactory. Previous studies have cited limited instructional resources, lack of student engagement, and poor pedagogical strategies as major contributors to this problem. There is a need to explore alternative instructional strategies that can motivate students and improve learning outcomes.

Can technology-based tools like PhET simulations and YouTube videos serve as effective interventions in improving physics learning? This research seeks to address this gap by empirically examining the effect of these tools on students' achievement and attitude.

Aim and objective of the study

The aim of this study is to investigate the impact of PhET simulation and YouTube video platforms on the achievement and attitude of physics students at the senior secondary school level. This study seeks to:

1. Determine the effect of PhET simulations on students' academic achievement in physics.
2. Examine the effect of YouTube video instruction on students' academic achievement in physics.
3. Compare the academic achievement of students taught with PhET Simulations, YouTube videos, and traditional teaching methods.
4. Assess the attitude of students toward physics after exposure to PhET simulations and YouTube videos.
5. Determine if there is a significant difference in the attitude of students across the three instructional methods.

Research Questions

The study is guided by the following research questions:

1. What is the effect of PhET simulation on students' achievement in physics?
2. What is the effect of YouTube video instruction on students' achievement in physics?
3. How does the academic achievement of students exposed to PhET simulations and YouTube videos compare with those taught using traditional methods?
4. What is the attitude of students toward physics after being taught with PhET simulations?
5. What is the attitude of students toward physics after being taught using YouTube video instruction?

Hypotheses

The following null hypotheses were formulated and tested at the 0.05 level of significance:

- Ho1: There is no significant difference in the achievement of students taught using PhET simulations and those taught using traditional methods.
- Ho2: There is no significant difference in the achievement of students taught using YouTube videos and those taught using traditional methods.
- Ho3: There is no significant difference in the academic achievement of students across the three instructional methods.
- Ho4: There is no significant difference in students' attitude toward physics after exposure to PhET simulations and YouTube videos.

Methodology

This study adopted a quasi-experimental design involving pre-test and post-test control groups. It involved three groups: Experimental Group A (taught using PhET simulations), Experimental Group B (taught using YouTube videos), and Control Group C (taught using traditional methods). The population comprised 1000 senior secondary school (SSS 2) physics students from selected schools in Minna, Niger State. A sample of 200 students was drawn using stratified random sampling, ensuring equal representation from each school and gender balance.

The sample was divided into: Group A (PhET): 70 students, Group B (YouTube): 65 students, Group C (Control): 65 students. Two instruments were used: Physics Achievement Test (PAT) - 30 multiple-choice items based on standardized physics curriculum topics.

Physics Attitude Questionnaire (PAQ) - a 4-point rating scale consisting of 20 items covering interest, confidence, and perception.

Both instruments were validated by physics educators and research experts. The reliability coefficients obtained using Cronbach's Alpha were: PAT = 0.86, PAQ = 0.88. The data was collected following this sequence of procedure: Week 1: Pre-test administered to all groups and Weeks 2-4: Treatment period.

Group A used PhET simulations for topics like Newton's Laws, Electricity, and Waves.

Group B was taught the same topics through selected YouTube videos.

Group C received traditional chalk-and-talk instruction.

Week 5: Post-tests administered.

Data were analyzed using SPSS Version 25. The following statistical tools were employed: Mean and Standard Deviation for descriptive analysis. ANOVA and t-tests were employed for hypothesis testing and the Significance level was set at 0.05. The analysis of data collected from 200 students divided into three groups was structured to address the research questions and test the corresponding hypotheses.

Research Question 1:

What is the effect of PhET simulation on students' achievement in physics?

Table 1: Descriptive Statistics of Achievement Scores for PhET Simulation Group (Pretest vs. Post-test)

Test Type	N	Mean	Std. Deviation
Pre-test	70	48.22	7.56
Post-test	70	82.15	5.42

Interpretation: There was a significant improvement in the mean score from pre-test (M = 48.22) to post-test (M = 82.15), Suggesting that PhET simulation positively impacted student achievement.

Research Hypothesis 1:

H₀₁, there is no significant difference in the achievement of students taught using PhET simulations and those taught using traditional methods.

Table 2: Independent Samples t-test (PhET vs Control Group Post-test Scores)

Group	N	Mean	SD
PhET Group	70	82.15	5.42
Control Group	65	67.88	7.01

SPSS Output - Independent Samples t-test:

Test Type	N	Mean	SD
Pre-test	65	49.11	6.82
Post-test	65	78.32	6.07

Interpretation: Students' achievement improved from a pre-test mean of 49.11 to a post-test mean of 78.32.

Research Hypothesis 2:

H₀₂: There is no significant difference in the achievement of students taught using YouTube videos and those taught using traditional methods.

Table 4: Independent Samples t-test (YouTube vs. Control Group Post-test Scores)

Group	N	Mean	SD
YouTube Group	65	78.32	6.07
Control Group	65	67.88	7.01

SPSS Output - Independent Samples t-test:

t	df	Sig. (2-tailed)	Mean Diff	Decision
8.33	128	0.000	10.44	Reject H ₀₂

Decision: Since $p < 0.05$, we reject H₀₂. YouTube instruction significantly improved student achievement compared to traditional teaching.

Research Hypothesis 3:

H₀₃: There is no significant difference in the academic achievement of students across the three instructional methods.

Table 5: One-Way ANOVA Summary.

Group	N	Mean	SD
PhET	70	82.15	5.42
YouTube	65	78.32	6.07
Traditional	65	67.88	7.01

ANOVA Output (Post-test Scores):

Source	SS	df	MS	F	Sig
Between Groups	7354.92	2	3677.46	96.73	0.000
Within Groups	5013.11	197	25.45		
Total	12368.03	199			

Post-hoc (Turkey) tests confirmed that all three group means differed significantly from each other.

Decision: Since $p < 0.05$, we reject H₀₃. There is a statistically significant difference among the three instructional methods, with PhET having the greatest impact.

Research Question 4 & 5: Attitude Analysis

Attitudinal data were measured on a 4-point Likert scale (1 = Strongly Disagree to 4 = Strongly Agree).

Table 6: Attitude Mean Scores (Post-Test)

Group	N	Mean	SD	Interpretation
PhET Group	70	3.82	0.41	Positive
YouTube Group	65	3.63	0.46	Positive
Control Group	65	2.98	0.51	Neutral
Grand Mean	200	3.48		Positive

Research Hypothesis 4:

H₀₄: There is no significant difference in students' attitude toward physics after exposure to PhET simulations and YouTube videos.

Table 7: One-Way ANOVA - Attitude Scores

Source	SS	df	MS	F	Sig
Between Groups	28.42	2	14.21	56.12	0.000
Within Groups	49.88	197	0.25		
Total	78.30	199			

Decision: Since $p < 0.05$, H₀₄ is rejected. Students exposed to PhET and YouTube had significantly more positive attitudes toward physics

Discussion of Findings

The findings of this study have revealed significant insights into how educational technologies, specifically PhET simulations and YouTube videos, impact students' learning outcomes in physics.

The first research question investigated the effect of PhET simulations on student achievement. The result indicated a substantial increase in post-test scores ($M = 82.15$), showing that interactive simulations enhance conceptual understanding. This supports the work of Wieman & Perkins (2006), who emphasized that PhET tools bridge theoretical gaps through visual and manipulative experiences. Similarly, students taught via YouTube videos ($M = 78.32$) performed better than those under traditional teaching ($M = 67.88$). This aligns with Mayer's (2009) multimedia learning theory, which states that combining visual and auditory channels enhances retention.

The ANOVA test for Hypothesis 3 confirmed significant differences among the three methods, suggesting that both PhET and YouTube are superior to the traditional approach. PhET, being more interactive, offered the highest improvement, possibly due to its experimental and feedback-

rich environment. Regarding attitude, students in the PhET group had the most favorable attitudes ($M = 3.82$), followed by YouTube ($M = 3.63$), while the control group scored only 2.98. These findings validate Ajzen's Theory of Planned Behavior, which postulates that engagement and perceived ease lead to positive attitudes. In general, the study supports prior research by Oludipe & Awokoya (2010), who found that integrating technology into science instruction enhances learner motivation, and Gulsecen & Kubat (2006), who reported positive behavioral changes when learners interact with digital platforms.

Summary

This research examined the impact of PhET simulations and YouTube video platforms on the achievement and attitude of senior secondary school physics students. A quasi-experimental design involving 200 students across three groups (PhET, YouTube, and traditional teaching) was used. Pre-tests and post-tests in achievement and attitude were administered.

The major findings are:

Students taught using PhET simulations and YouTube videos performed significantly better than those taught traditionally. PhET simulations had the most positive effect on student achievement. Both PhET and YouTube significantly improved students' attitudes toward physics. The traditional method lagged behind in both achievement and attitude scores.

Recommendations

Based on the findings, the following recommendations are made:

Curriculum Integration: Educational stakeholders should incorporate PhET simulations and relevant YouTube content into the senior secondary physics curriculum.

Teacher Training: Teachers should receive periodic training on how to integrate and use simulation tools and educational videos effectively.

Government and NGOs Support: Provision of computer labs, internet access, and multimedia resources should be prioritized to support tech-enhanced learning.

Content Curation: Schools and teachers should carefully select scientifically accurate and curriculum-aligned YouTube content.

Blended Learning: A hybrid instructional model combining simulations, videos, and traditional teaching may maximize student outcomes.

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INFORMATION COMMUNICATION TECHNOLOGY SKILLS ON STUDENTS USE OF LIBRARY RESOURCES IN FEDERAL POLYTECHNICS IN NORTH-EAST, NIGERIA

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Abstract

This study investigated Information Communication Technology (ICT) skills on students use of library resources in federal polytechnics in North-east, Nigeria. Three research questions guided the study in line with the research objectives. The study adopted descriptive survey research design. The study population comprised one thousand HND students that registered with polytechnic libraries in North-east, Nigeria with sample size of 500 HND students. The study employed multi-stage sampling technique to determine the sample size. A structured questionnaire was the instrument for data collection. Data were analysed using frequency counts, percentage and mean with criterion mean of 2.50 benchmark. Findings revealed that the extent of the use of library information resource by students was high; possession of ICT skills had a high influence on students use of library information resources and there is a significant influence of possession of ICT skills on the use of library information resources by students in federal polytechnics in North-east, Nigeria. Based on the findings, the study concluded that majority of the respondents used printed information resource than the electronic resources in federal polytechnics in North-east, Nigeria. The study recommended that the management of the polytechnic libraries in North-east, Nigeria should leverage on the ICT skills possessed by the students to put in place services that would facilitate the use of electronic resources in federal polytechnic libraries studied.

Keywords: Federal Polytechnics, ICT Skills, Use of Library Resources, North-East, Nigeria

Introduction

Use of library information resources involves utilizing various materials by patrons available in the libraries to support research, education, and personal enrichment. These library resources include books, electronic database, journals and multimedia materials. Users can access these resources to find information, conduct research, enhance their knowledge and complete academic or personnel projects. Library information resources are typically organized by librarians and made available to help users locate the information they need. By effectively using library information resources individual can broaden their horizons, stay informed and engage in lifelong learning. Innocent (2022) stated that the use of library and information resources is very important as to the research output of researchers in universities, because it is perceived that the use of these resources may contribute to the research output and the development of the nation at large. Consequently, Mwalukasa (2022) asserted that the use of information resources in libraries help to fulfill the objectives of establishing the university and these enables the university library supports to accomplishment of the main objective of higher learning institution in provision of high quality education.

Information and Communication Technology (ICT) refers to technology that provides access to information via telecommunications devices and infrastructure. ICT is the coming together of computing, telecommunication and broadcasting technologies to produce information. Example of computing technologies are the computers and their accessories, telecommunication technologies include: telephone, facsimile, fax, e-mail while the broadcasting technologies include: radio, television, video. ICT can also be defined as the science of information processing which deals with the use of computer and other electronic devices to collect, process, store, retrieve and transmit or disseminate information to any part of the world (Adamu, 2023). Similarly, Chaudhar and Bhoje. (2024) asserted that Information and Communication Technology (ICT) in libraries is the application of digital equipment to all aspects of library work. It is the type of technology that links the computer to global computer network to make it possible for users to access information.

Information and Communication Technology (ICT) skills could be viewed as the overall competencies, knowledge, abilities and technical know-how needed to create, save, analyse, organise, retrieve and disseminate digital information such as images, text, sounds and graphics in digital libraries or any other type of information. ICT skills are those skills that enable an individual to use computers, software applications, databases and other technologies to achieve a wide variety of academic work-related and personal goals. ICT skills is the proficiency to use computers, software and related technologies to perform specific tasks in order to provide information, generate knowledge and solve attendant problems (Ocheni *et al.*, 2023). Similarly, Amir and Yuliartini (2024) defined ICT skills as the ability to effectively use technology to access, analyze, evaluate and create information available online, communicate effectively and leverage technology for various purposes. The provision and use of ICT is part and parcel of the entire system, include education, business, hospital, postgraduate research, information professional staff and researchers. It is one thing to recognize the importance to ICTs and another to know if they are effectively used by students. ICT were to be effectively applied directly or indirectly on the utilization of information resources, as such skills are required for the operation. Liesa-Orús *et al.* (2020) stated that ICT skills are one essential requirement for one to operate in the technology society of the 21st century. Ahmed and Sheikh (2020) described ICT skills as the abilities for the collection, effective processing, storing transmitting and dissemination of information which enables the use of computer and related technologies to meet personal academic and labour market objectives. An ICT skill of a student is a relative measure of the student capacity to make appropriate use of ICT device or equipment's. ICT skills are required to critically evaluate information content and explore it effectively, as well as understanding the technology infrastructure on which information transmission is based (Saikkonen and Kaarakainen 2021).

There is every tendency that the capacity of a library user to exploit ICT related information resources in any institution library such as polytechnic library will depend on the level of his/her ICT skills possession, education and mastery of the technologies involved. Thus, it is against this backdrop that the researcher intends to investigate Information Communication Technology skills on students use of library information resources in federal polytechnics in North-east, Nigeria.

Statement of the Problem

The use of the library information resources is crucial for continue existences of the library. It helps in the conduct of research, gaining of knowledge and accessing of a wide range of learning

materials. Libraries provide a vast collection of books, journals, magazines, newspapers, and other resources that can support individuals in their academic studies, professional development, or personal interest. The regular or frequency use of the library resources would help users improve their reading and comprehension skills. Preliminary investigation showed that polytechnic library in North-east, Nigeria are always full to their capacity during examination periods but experience low patronage when the examinations are over.

Extant literature has shown that majority of students in tertiary institutions in Nigeria does not make good use of library information resources as evident by Issa *et al.* (2024). Mashaba and Pretorius (2023) equally reported that students in Nigerian tertiary institutions under use the library information resources (both print and electronic) as this could result to poor academic performance. Poor academic performance is as a result of poor knowledge acquisition which inventionally leads to not meeting society's requiremet for emplyment, poor standard of living, non-measuring up in the society and bad behaviour such as stealing, lack of user education programmes and inadequate possession of ICT skills by students of federal polytechnics in North-east, Nigeria. To address this research concern, the researchers investigated Information Communication Technology skills on students use of library resources in federal polytechnics in North-east, Nigeria.

Objectives of the Study

The objectives were to:

1. determine the extent of use of library information resources by students in federal polytechnics in North-east, Nigeria;
2. ascertain how possession of ICT skills influence the use of library information resources by students in federal polytechnics in North-east, Nigeria;
3. determine the significant influence of possession of ICT skills on the use of library information resources by students in federal polytechnics in North-east, Nigeria.

Research Questions

The following research questions guided the study:

1. What is the extent of use of library information resources by students of federal polytechnics in North-east, Nigeria?
2. How does the possession of ICT skills influence the use of library information resources by students of federal polytechnics in North-east, Nigeria?
3. Is there any significant influence of possession of ICT skills on the use of library information resources by students in federal polytechnics in North-east, Nigeria?

Literature Review

Library information resources refers to various information materials that are available in the libraries to support teaching, learning and research. These resources include: Print materials such as Books, Journal, Magazines, Newspaper, and Reference materials, digital materials such as Electronic Books, Online Databases, Electronic Journals, and Digital Archives, Multimedia; DVD, CD, Audio books, and other Audio-visual materials, Special Collections; Rare books, Manuscripts, and Unique archival materials. These resources are collected organized and made accessible to the library users to support their research, study, and information needs. (American Library Association, 2020).

Ilesanmi (2023) conducted a study to examine librarians' ICT skills and service delivery in private universities in Nigeria. The study was guided by three research questions in line with the research objectives. The study adopted survey research method. The population of the study comprised 181 librarians in the 45 private universities in Southern, Nigeria. Data collection instrument was questionnaire. Data was statistically analysed using frequency counts, percentage, mean and chart. Findings revealed that librarians delivered various library services to their users, acquired basic ICT skills and were versatile in its application for Internet searches, information retrieval, social communication and Microsoft-office related activities with the exception of programming skills. Majority of librarians acquired their ICT skills through self-learning. The study concluded that acquisition of ICT skills by librarians is relevant to their delivery of improved library services. The study recommended that regular acquisition of relevant ICT skills is essential for librarians and university management should support librarian's ICT capacity development at national and international levels as this would enhance their relevance and get them abreast of the latest development for effective service delivery.

Oyeyemi (2022) conducted a study to investigate the impact of ICT on academic performance of students at the Federal Polytechnic, Idah, Nigeria. The study was guided by four research hypotheses in line with research objectives. The study adopted descriptive survey research design. The population of the study comprised 500 library users with sample of 250 users. Data collection instrument was structured questionnaire divided into two sections A and B. Data collected were statistically analysed using simple percentages and hypotheses were inferentially analysed using chi-square. Findings revealed that there is significant relationship between the ICT facilities available for use and users, no significant relationship between the ICT tools and the purpose of use, there was a significant relationship between ICT tools and means by which the students accessed it for use and there was very high relationship between the use of ICT tools and the problem, ICT facilities and purpose of use has composite impact or influence of 51.2 % on academic performance. The study concluded that there was low level of use of ICT facilities. The study recommended among other things that effort should be intensified to create thorough awareness on the integration of ICT facilities into curricula activities in our various schools, and training retraining programme should be organised consistently for information managers to improve and update their knowledge on ICT facilities.

Onyenachi *et al.* (2021) conducted a study to investigate the use of ICT in university libraries by undergraduate students: A case of Abia State University, Uturu, Nigeria. The study was guided by three research questions in line with the research objectives. The study adopted descriptive survey design. The population of the study comprised 3770 registered undergraduate students in the library while 10% of the population which is 377 was the sample size used for the study. Data collection instruments were questionnaire and observation checklist. Data was statistically analysed using mean rating at 2.50 as benchmark. The result showed that computers, Wi-fi, interrupted power supply, CD-ROM, computer networks were available while printers, scanners, modem and photocopiers were not available. Inadequate ICT equipment, inadequate access to compatible software facility and lack of skilled ICT personnel were found to be the challenges. The study concluded that adequate funding of university libraries as to purchase adequate ICT facilities, recruitment of skilled staff, easier accessibility to compatible software facilities, training and retraining of library staff, faster pace of Internet connectivity will increase the use of the ICT facilities in the library. The study recommended among other things that printers, scanners, modem

and photocopiers should be made available, adequate ICT equipment be made available, access to compatible software facilities be made available and skilled ICT personnel should be made available.

Akanbe *et al.* (2021) conducted a study to investigate the influence of information and communication technology on library use by undergraduate students at the University of Ilorin, Nigeria. Descriptive survey design was adopted for the study. The study was guided by five (5) research question in line with the objectives. Random sampling technique was used to select a sample size of 100 undergraduate students of four selected faculties in the university were selected to be the respondents; A structured questionnaire was use as the instrument for data collection. Data was analyze using frequency, percentage, mean and standate deviation. Findings revealed that the undergraduate students of the university can make use of ICT tools without any difficulties and they are well informed when it comes to ICT gadget usage in University of Ilorin library, The undergraduate students have easy accessibility to electronic resources in the library with ICT tools and library operations, it encourages current information and improve ICT skills of student, among others. The challenges are outdated library software, poor internet connectivity and restriction from usages of ICT gadget in the library. The study concluded that user education programme significantly influenced the use of electronic resources by the undergraduates. The study recommended that, there should be stability of power and availability of internet service within the library and the campus.

Akanbe *et al* (2020) conducted a study to investigate the influence of ICT skills on library information resources utilization by undergraduate students in two universities in South-west, Nigeria. Descriptive survey research was adopted for the study. From a population of 32,419 undergraduate students in the University of Ibadan and the Obafemi Awolowo University, Ile-Ife, a multi-stage sampling technique was used to select 407 respondents. Questionnaire was the instrument used for data collection. Descriptive statistics such as frequency, percentage and mean distribution were used to analyze the data collected. Pearson's correlation coefficient was used to test the hypotheses at 0.05 level of significance. Findings of the study showed that ICT skills possessed by the undergraduate students were high, the extent of library information resources utilization by undergraduate students was generally low; however reference materials and monographs/textbooks were highly utilized. The result also revealed that there was significant positive correlation ($r = .383^{**}$; $p < 0.05$) between ICT skills and library information resources utilization. Thus, The study concluded that ICT skills of undergraduates has a positive influence on the utilization of library information resources, especially when the information resources requires the application of ICT directly, the study recommend that the management should provide ICT facilities in the library and the provision of power at all time.

Sahabi and Omagbon (2020) conducted a study to investigate the undergraduate students' use of electronic information resources and information literacy skills in university libraries in Nigeria, The survey research design was employed and the study was guided by five (5) research questions inline with the research objectives. The instrument used for data collection was the Questionnaire. Simple tables and percentages were used to analyze the data collected. Findings revealed that University Libraries automated/computerized apply Strategic Library Automation Management (SLAM); only three divisions of the libraries are computerized/automated which are Readers Services Division, Technical Services Division and Collection Development division; the major

reason attached to the use of ICT resources was for information storage and retrieval; the ICT resources mostly used are CD-ROM, online database, World Wide Web and the Internet. The study equally revealed that ICT has an enormous impact based on its effectiveness. Inadequate training and retraining of staff by management; inadequate funding, epileptic power supply and lack of search skills were the major factors militating against the effective use of ICT in Nigerian University libraries. The study concluded that ICT has fulfilled its promise in academic libraries and there is a remarkable rise in the use of ICT which, many of the libraries activities are now ICT driven. The study recommends that there should be an adequate funding of the libraries, capacity building, and regular power supply in the libraries so that the ICT devices can be utilized at all time.

Idakwo *et al.* (2018) conducted a study to investigate the application of information and communication technology in circulation operations in selected Federal University Libraries in North-Central, Nigeria. The study was guided by five research questions in line with the research objectives. The study adopted survey research design. The population of the study comprised 30 circulation staff of University of Ilorin, Federal University Lokoja and University of Abuja Libraries. The instrument used for the study was a structure questionnaire. Data collected were analysed using simple percentage. Findings of the study revealed that ICTs are utilised in circulation operations in the federal university libraries; ICT devices are available for circulation operations in the libraries among others. The study recommended that government should endeavour to provide adequate funds for procurement of ICT facilities for university libraries to enhance automation of circulation operations and university management should engage the circulation staff on continuous ICT training through organised seminars and workshops and among others.

Methodology

This study adopted descriptive survey research design. The descriptive survey research design was used because it is a survey type of research that is characterized by population and sample as well as the use of data collection instrument. The study population comprised one thousand (1,000) Higher National Diploma (HND) students that registered with libraries in federal polytechnics in North-east, Nigeria as at 2024/2025 academic session. The sample size was 500 registered HND students with polytechnic libraries and was determined using 50% sample fraction. A close-ended structured questionnaire was the instrument for data collection. Data were analysed using frequency counts, percentage and mean with criterion mean of 2.50 benchmark. Weighted mean above or equal to the criterion mean scores were considered high extent or positive influence while weighted means below the criterion mean scores were considered low extent or negative influence. The draft copies of questionnaire were validated by four lecturers in the Department of Library Information Science and two experts from Department of Test and Measurement all from Federal University of Technology, Minna for correctness and appropriateness of the language used, whether it is suitable and appropriate to answer the research questions of the study. The researchers administered 30 copies of the questionnaire to HND students in federal polytechnic, Bida and federal polytechnic, Kaduna for pilot testing using test re-test method. The overall reliability coefficient was 0.88 indicating that the instrument is reliable and excellent. A total of 500 copies of questionnaire were administered to HND students and 482 copies of questionnaire were retrieved representing 96.4% response rate.

Results

Research Question One: What is the extent of use of library information resource by students in federal polytechnics in North-east, Nigeria?

Table 1: Extent of use of library information resource by students in federal polytechnics in North-east, Nigeria

S/N	Statement	VHE		HE		LE		VLE		N	FX	Mean	Decision
		(4)		(3)		(2)		(1)					
		Fq	%	Fq	%	Fq	%	Fq	%				
1	I use the textbooks in my institutional library for assignment.	267	55.4	188	39.0	27	5.6	0	0	482	1686	3.49	High
2	I use the electronic books in my library for seminars.	160	33.2	157	32.6	32	6.6	133	27.6	482	1308	2.71	Low
3	I consult Journals for latest information and get new updates on a subject of study	230	47.7	168	34.9	77	16.0	7	1.5	482	1585	3.28	High
4	I use electronic journals as they carry first-hands information of new ideas or discoveries.	137	28.4	157	32.6	1	0.2	187	38.8	482	1244	2.58	Low
5	I check the newspapers in my library for daily news headlines.	246	51.0	184	38.2	45	9.3	7	1.5	482	1633	3.39	High
6	I browse through the electronic newspapers always for news update.	60	12.4	149	30.9	65	13.4	208	42.8	482	1025	2.13	Low
7	I consult reference materials. (Such as Dictionaries, Yearbooks, Gazetteers, and Encyclopaedias.) For meaning of words, fact about past events, information or data about discussion.	297	61.6	158	32.8	27	5.6	0	0	482	1716	3.56	High

8	I use electronic database in my library to search for a particular document.	199	41.3	209	43.4	62	12.9	12	2.5	482	1559	3.23	High
												3.05	

Weighted Mean

Decision Mean: Average Weighted Mean = 3.05

Table 1 presented the extent of use of library information resources by students in federal polytechnics in North-east, Nigeria. The result showed that the respondents indicated that the following library information resources were highly used: reference materials with mean score of (3.56), textbooks with mean score of (3.49), newspapers with mean score of (3.39), hard copy journals with mean score of (3.28) and electronic databases with mean score of (3.23). However, electronic books with mean score (2.71), electronic journals with mean score of (2.58), and electronic newspapers with mean score of (2.13) recorded low extent of usage. Generally, the extent of use of library information resource by students in federal polytechnics in North-east, Nigeria was high with the average weighted mean of 3.05 which is above the criterion mean of 2.50 benchmark.

Research Question Two: How does the possession of ICT Skills influence the use of library information resources by students in federal polytechnics in North-east, Nigeria?

Table 4.8: Possession of ICT Skills influence on the use of library information resources by students in federal polytechnics in North-East, Nigeria

S/N	Statement	VHE (4) Fq		HE (3) Fq		LE (2) Fq		VLE (1) Fq		N	FX	Mean	Decision
			%		%		%		%				
1	My ability to open web pages enhances the use of online information resources in the libra	397	82.4	84	17.4	1	.2	0	0	482	1842	3.82	High
2	I have the knowledge to navigate web links and this enhances the use of online information resources in the libra	314	65.1	165	34.2	3	0.6	0	0	482	1757	3.65	High
3	Ability to save favourite web pages enhances the use of online information resources in the libra efficientl	253	52.5	228	47.3	1	0.2			482	1698	3.52	High
4	My ability to use Survey Monkey or Google Form to collect research data enhances the use of online information resources in the library.	0	0	238	49.4	9	1.9	235	48.8	482	967	2.01	Low
5	My knowledge of ICT enables the use of online reference sources in the library.	446	92.5	36	7.5	0	0	0	0	482	1892	3.93	High
6	My knowledge of ICT enhances the use of online serial publications in the library.	331	68.7	134	27.8	12	2.5	5	1.0	482	1755	3.64	High

7	My ability to perform networking activities enhances the use of online information resources in the library.	262	54.4	206	42.7	13	2.7	1	0.2	482	1693	3.51	High
8	Ability to collaborate and share ideas online with my colleagues enhances the use of information resources in the library.	308	63.9	168	34.9	4	0.8	2	0.4	482	1746	3.62	High
9	My ability to share research findings with other people on social media such as WhatsApp, Facebook, Instagram enhances the use of online information resources in the library.	482	100	0	0	0	0	0	0	482	1928	4.00	High
10	My ability to use search engines such as Google, Mamma, Yahoo enhances the use of information resources in the library.	379	78.6	103	21.4	0	0	0	0	482	1825	3.79	High
11	Ability to search and retrieve research papers on ResearchGate enhances the use of online information resources in the library.	5	1.0	192	39.8	26	5.4	259	53.7	482	967	2.01	Low
12	My ability to search and retrieve research papers on Google Scholar enhances the use of online information resources in the library.	367	76.1	115	23.9	0	0	0	0	482	1813	3.76	High
13	My ability to use bibliographic database such as OPAC to retrieve information enhances the use of information resources in the library.	14	2.9	190	39.4	19	3.9	259	53.7	482	924	1.92	Low
14	Ability to use full-text databases to retrieve information enhances the use of information resources in the library.	229	47.5	242	50.2	11	2.3	0	0	482	1664	3.45	High
15	My knowledge of ICT enables me to use Web OPAC and this enhances the use of information resources in the library.	379	78.6	98	20.3	5	1.0	0	0	482	1815	3.77	High
Weighted Mean												3.36	

Decision Mean: Average Weighted Mean =3.36

Table 2 presented the influence of possession of ICT skills on the use of library information resources by students in federal polytechnics in North-east, Nigeria. The result showed that the respondents perceived that twelve (12) out of fifteen (15) items listed on possession of ICT skills had high influence on the use of library information resources as the mean scores were above or equal to the average weighted mean of 3.36. On the other hand, the respondents perceived that the remaining three (3) items had low influence on the use of library information resources. Generally, the influence of possession of ICT skills on the use of library information resources by students in

federal polytechnics in North-east, Nigeria was high with the average weighted mean of 3.36 which is above the criterion mean of 2.50 benchmark.

Research Question Three: Is there any significant influence of possession of ICT skills on the use of library information resources by students in federal polytechnics in North-east, Nigeria?

Table 3: ANOVA Model of Regression Analysis of possession of ICT skills on the use of library information resources by the students of federal polytechnics in North-east, Nigeria.

Model	Sum of Squares	df	Mean Square	F	Sig
Regression	99.077	2	99.077	701.707	0.00
Residual	67.773	480	0.141		
Total	166.850	482			

- a. Dependent Variable: use of library information resources
- b. Independent Variable(predictors) Constant: the possession of ICT skills

Table 3 showed Regression Sum of Squares = 99.077 which quantifies the variation in the dependent variable that the model explains. Residual = 67.773 quantifies the unexplained variation or error in the model. Total Sum of Squares = 166.850 quantifies the total variation in the dependent variable. Regression Mean Square = 99.077 explains the average amount of variation explained by the regression model. The F-statistic = 701.707 showed the regression model explains a high significant portion of the variation in the dependent variable. This p-value = 0.000 indicates the overall regression model is statistically significant since ($0.000 < 0.05$). Consequently, the hypothesis which states that there is no significant influence of possession of ICT skills on the use of library information resources by the students of federal polytechnics in North-east, Nigeria is rejected. Hence, there is a significant influence of possession of ICT skills on the use of library information resources by the students of federal polytechnics in North-east, Nigeria.

Discussion of Findings

Research objective one sought to find out the extent of use of the library information resources by students of federal polytechnics in North-east, Nigeria. Findings revealed that there is a high extent of use of the library information resources by students of federal polytechnics in North-east, Nigeria. This implies that students fully utilised the library information resources available in federal polytechnic libraries in North-east, Nigeria. This finding is in line with the findings of American Library Association (2020) that library information resources are acquired, organized and made accessible and by users to support their research, study, and information needs. This finding corroborates with finding of Innocent (2022) that use of library and information resources is very important as to the research output of researchers in Nigerian universities, because it is perceived that the use of these resources may contribute to the research output and the development of the nation at large. Similarly, Mwahukasa (2022) reported that most of the respondents mainly used special collection, general collection and special reserve at Sokoine University of Agriculture,

Tanzania. Joseph *et al.* (2020) reported that over 50 % of the students use the library to consult resources on a regular basis at Rufus Giwa Polytechnic Library, Owo, Ondo State, Nigeria.

Research objective two sought to find out possession of ICT skills influence on use of library information resources by students of federal polytechnics in North-east, Nigeria. Findings revealed that possession of ICT skills influence on use of library information resources by students of federal polytechnics in North-east, Nigeria was high. This implies that students of federal polytechnics in North-east, Nigeria had a requisite ICT skill that enable them to use library information resources effectively. This finding corroborates the findings of Akanbe *et al.* (2020) that student's possession of ICT skills influenced the use of library resources at University of Ilorin, Nigeria. Consequently Adamu (2023) reported that possession of ICT skills has a positive influence on job performance of librarians in federal university libraries in Nigeria.

Research objective three sought to find out if there is any significant influence of possession of ICT skills on the use of library information resources by students in federal polytechnics in North-east, Nigeria. The result was rejected, this implies that there is a significant influence of possession of ICT skills on the use of library information resources by the students of federal polytechnics in North-east, Nigeria. This finding corroborates the findings of Akanbe *et al.* (2020) that student's possession of ICT skills influenced the use of library resources at University of Ilorin, Nigeria. Consequently, Adamu (2023) reported that possession of ICT skills has a positive influence on job performance of librarians in federal university libraries in Nigeria.

Conclusion

Based on the findings, The extent of use of library information resources was high, possession of ICT skills had a high influence on the use of library information resources and there is a significant influence of possession of ICT skills on the use of library information resources by the students. Thus, the study concluded that majority of the respondents used printed information resource than the electronic resources in federal polytechnics in North-east, Nigeria.

Recommendations

Based on the findings, the following recommendations were made:

1. The management of Federal Polytechnics in North-east, Nigeria should leverage on the possession of ICT skills of students and put in place services that would facilitate the use of electronic resources in the library.
2. The management of Federal Polytechnics in North-east, Nigeria should introduce more user education programmes to include digital literacy programmes.
3. The management of Federal Polytechnics in North-east, Nigeria should prioritise the use of electronic resources by providing more computer system and Internet in the library.

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COMPUTER NUMERICAL CONTROL MACHINES SKILLS AND COMPETENCIES REQUIRED BY CARPENTRY AND JOINERY TEACHERS FOR GROOVING AND REBATING OPERATIONS IN TECHICAL COLLEGES IN KANO STATE, NIGERIA

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Abstract

The study focused on the skills and competencies assessment required for Computer Numerical Control Woodworking Machines (CNCWMs) operations for technical colleges carpentry and joinery in Kano State Nigeria. The study was carried out in some selected Government Technical Colleges (GTCs) in Kano State. Three objectives of the study were stated to guide the study. The population for the study was 147 carpentry and joinery courses teachers and students in the area of the study. There is purposive sampling on teachers and students in the selected technical colleges' (TCs) carpentry and joinery departments due to the manageable population in the department in the area of study. The instrument for data collection was a questionnaire developed from literature reviewed and validated by three woodwork experts from Department of Woodwork Technology Education, Federal College of Education (Technical), Bichi, Kano State– Nigeria. The questionnaire was administrated on 147 respondents which include teachers and students of carpentry and joinery department in three selected TCs in Kano State, and 124 retrieved and analyzed using mean and standard deviation (SD). The study revealed among others that the skills and competencies required for CNCWMs operations for Carpentry and Joinery should be properly put into use to enhance the effective and practicable teaching of carpentry and joinery courses to improve students' interest, understanding and better comprehension in the subject, TCs to provide necessary tools and equipment that will promote the teaching and learning of carpentry and joinery courses in TCs across the country among others. Recommendations were given based on the findings from the study.

Keywords: *Computer Numerical Control Woodworking Machines (CNCWMs), Skills, Competencies, Carpentry and Joinery, and Assessment.*

Introduction

The CNCWMs can be defined as the computerized technology in which functions and motion of the woodworking machine tools are controlled by means of a prepared programme (software) containing coded alphanumeric programme data (Samaila & Aminu, 2021). The CNCWMs based processes have been developed to meet extra required machining conditions. CNCWM is electro-mechanical device that manipulate tools using computer programming inputs. It is the name given to a machine containing a spindle or router that receives its fabricating marching orders from a computer such as laptop or desktop unit containing Computer Aided Design (CAD) software.

Carpenters and joiners are craftsmen which normally work at a bench and are mainly concerned with construction of movable wood items of carpentry and joinery. They focus on fitting of joints to produce high quality sound carpentry and joinery made from specially selected figure wood to

produce carpentry and joinery works. Carpenters and joiners required sound knowledge of design principles, working properties of the materials, construction method, decoration and fittings techniques (Walton, 1978). Haruna (2021) stresses that, a well train carpenters and joiners has to put all the principle of design and construction into consideration. While Lawal (2019) stated that, the end product determines how skillful the worker is, that is ability to have sound knowledge of materials, hand and driving tools and their used as well as the need of the society in Carpentry and Joinery.

Skill is the ability to do something expertly well or perform a task to an acceptable standard when measured against. According to Makama (2019), skill is anything that an individual has learned to do with ease and precision and may be either physical or mental performance, involving manipulative proficiency in hand finger and eye coordination. Osinem and Nwaoji (2022), define skill, as the proficiency displayed by someone in performance of a given task. It is a person's ability in performing a given task well as a result of training and practice. Skill is having enough ability, experience and knowledge, to be able to do something well. Uga (2023), stress that, skill is well-established habit of doing things by people. In the context of this study, skill is the ability that an individual has acquired or improve upon that will enable him performs a task efficiently in woodwork using CNCWMs. The skill that the teachers and students acquired need to be assessed for effective service delivery.

Competency is an essential ability obtained in a profession and those which the professional in the field must possess and be able to demonstrate at optimal level of functioning. Odewumi and Dekom (2020) referred to competency as knowledge, skills and attitude that are required for successful performing of the task. Competency as applied in this study is the knowledge, skills and attitude or training ability carpentry and joinery teachers and students must assess the operational skills and competencies using CNCWMs for effective delivery of practical skills and competencies class without difficulties. CNCWM has revolutionized the world of highly precise woodworking.

Assessment is a form of evaluation that uses collected data for estimating the work quality or effectiveness of a programme or project. Assessment involves use of empirical data on students learning (Baer *et al.*, 2016). Assessment is the wide variety of methods or tools that educators use to evaluate measure and document academic readiness, learning progress, skill acquisition, or educational needs of the teachers and students. Valid assessment of people helps someone to pass judgment correctly. With reference to this study, assessment is the process of evaluating skills and competencies required with CNCWMs operations for furniture crafts in TCs through collection of data from them to determine the level of skills and competencies they possess in operating CNCWMs for effective and efficient instructional delivery, despite the availability of CNCWMs in TCs offering National Technical Certificate (NTC) carpentry and joinery programme. Hence, the need to assess the level of skills and competencies of teachers and students on operating CNCWMs in TCs in Kano State, Nigeria.

Statement of the Problem

Carpentry and joinery teachers implement the prepared curricula in various TCs offering NTC programme for students' acquisition and competencies. It was noted that carpentry and joinery teachers in Kano State TCs are not fully prefer to operate CNCWMs for teaching students' skills and competencies despites the availability of the CNCWMs in Kano State TCs and also, the

CNCWMs are easy to operate by anybody in carrying-out the grooving, rebating, carving, and others woodworking operations. Again, woodwork craftsmen operating the CNCWMs in their day-to-day carpentry and joinery in their respective work places. The needs to assess their level of skills and competencies they possessed for operating CNCWMs for carpentry and joinery teachers and their students.

The problem of this study therefore, is to assess the extent to which the carpentry and joinery teachers and their students in TCs can operate CNCWMs in making carpentry and joinery articles during practical skills and competencies lesson delivery in Kano State. The huge amount of money spent in purchasing the CNCWMs into their TCs is presently a source of concern to stakeholders. The time also spent in training and retraining them is also of greet worry to academics and industrialists. All these concerns therefore justify the need for this study.

Aim and Objectives of the Study

The study was designed to assess the extent to which skills and competencies of carpentry and joinery teachers are capable to operate the CNCWMs in practical lesson delivery to their students in Kano State TCs. Specifically, the study assessed:

1. CNC machine skills required by carpentry and joinery teachers for grooving in technical colleges of Kano State;
2. CNC machine skills required by carpentry and joinery teachers for rebating operation in technical colleges of Kano State.

Research Questions

The following research questions were raised to guide the study:

1. What are the CNC machine skills required by carpentry and joinery teachers for grooving in technical colleges of Kano State?
2. What are the CNC machine skills required by carpentry and joinery teachers for rebating operation in technical colleges of Kano Stats?

Research Methodology

Descriptive survey research design was considered suitable for this study. This research design is mostly applied to real life situation in education where need to assess the operational skills and competencies of CNCWMs for carpentry and joinery teachers. Olaitan *et al.* (2020) stated that the descriptive survey research design is the plan, structure and strategy that the researcher wants to adopt in order to obtain solution to research problems using questionnaire in collecting, analyzing and interpreting the data. Questionnaires was used to collect data from carpentry and joinery teachers and their students from TCs offering NTC furniture crafts programme in order to assess their operational skills and competencies in using CNCWMs in delivering their practical lesson with the students. The area of the study was Kano State TCs offering NTC furniture crafts programme as: Government Technical College (GTC) Gwarzo, GTC Karaye and GTC Rogo. The population of the study is 147 respondents. 70 carpentry and joinery students, 29 carpentry and joinery teachers and 48 carpentry and joinery craftsmen. The carpentry and joinery craftsmen used for the study were use purposive sampling technique. This was achieved by engaging the students to give questionnaire to the carpentry and joinery craftsmen that lead to engaged them during the Students Industrial Work Experience Scheme (SIWES) exercise. The instrument used for the data collection titled: Woodworking Machines Computer Numerical Control Skills and Competencies

Assessment for Carpentry and Joinery Questionnaire (WMCNCSCACJQ) was developed based on literature reviewed. The instrument was validated by three woodwork technology experts, from the Department of Woodwork Technology Education, Federal College of Education (Technical), Bichi, Kano State. The instrument was pilot tested for reliability by using it for 13 carpentry and joinery teachers and their 23 students for GTC Hunkuyi, Kaduna State which is outside the area of the study as well as 15 carpentry and joinery craftsmen from Zaria Metropolitan were also, used for reliability obtained 0.88 which is outside the area of the study. These implies that the instrument was reliable. The data were collected by using the WMCNCSCACJQ instrument by the researcher who distributed the instruments to the students while other copies were distributed to carpentry and joinery craftsmen who engaged them in the carpentry and joinery works. One hundred and twenty-four copies of the questionnaires were filled and returned representing about 77 percent retrieval rate to the carpentry and joinery craftsmen. The one filled by students were filled by the students were all returned indicating 95 percent retrieval rate by the students. Data collected were analyzed using the Statistical Package for Social Sciences (SPSS) version 25. The mean and standard deviation was used to answer the research questions and the one-way Analysis of Variance (ANOVA) was used to analyze or test the hypotheses at 0.05 level of significance. When the mean value is less than 3.50 is Not Enhanced while, when mean value is greater than 3.50 is Enhanced. And also, hypotheses tested at 0.05 level of significance, if the level of significant is below or less than ($p < 0.05$) therefore the result shows that: there is significant or accepted in the testing hypothesis while, if the level of significant is above or greater than ($p > 0.05$) therefore the result shows that: there is no significant or rejected.

Results

Table 1: Table of respondents of the extent to which CNCWMs had enhanced grooving operation delivery in carpentry and joinery in TCs workshops

Respondents	No.	Mean	SD	Decision
C & J Students	98	3.60	0.71	Enhanced
C & J Craftsmen	50	3.35	0.86	Enhanced
C & J Teachers	10	3.41	0.88	Enhanced

Key: C & J = Carpentry and Joinery

The table 1 showed above is the grooving operation using CNCWMs for carpentry and joinery. The mean of the opinion of the carpentry and joinery teachers was 3.60, carpentry and joinery students was 3.41 and carpentry and joinery craftsmen 3.35 and also, Standard Deviation (SD) was 0.71, 0.86 and 0.88 for carpentry and joinery teachers, carpentry and joinery students and carpentry and joinery craftsmen respectively.

Table 2: Table of respondents of the extent to which CNCWMs had enhanced rebating operation delivery in carpentry and joinery in TCs workshops

Respondents	No.	Mean	SD	Decision
C & J Students	98	2.46	0.81	Not Enhanced
C & J Craftsmen	50	2.52	0.92	Not Enhanced
C & J Teachers	10	2.63	0.94	Not Enhanced

The table 2 showed above is the rebating operation using CNCWMs for carpentry and joinery. The mean of the opinion of the carpentry and joinery teachers was 2.63, carpentry and joinery students were 2.46 and carpentry and joinery craftsmen 2.52 and also, Standard Deviation (SD) was 0.94,

0.81 and 0.92 for carpentry and joinery teachers, carpentry and joinery students and carpentry and joinery craftsmen respectively.

Table 3: Table of respondents of the extent to which CNCWMs had enhanced carving operation delivery in carpentry and joinery in TCs workshops

Respondents	No.	Mean	SD	Decision
C & J Students	98	2.65	0.83	Not Enhanced
C & J Craftsmen	50	2.34	0.94	Not Enhanced
C & J Teachers	10	2.45	0.85	Not Enhanced

The table 3 showed above is the carving operation using CNCWMs for carpentry and joinery. The mean of the opinion of the carpentry and joinery teachers was 2.45, carpentry and joinery students was 2.65 and carpentry and joinery craftsmen 2.34 and also, Standard Deviation (SD) was 0.83, 0.85 and 0.94 for carpentry and joinery teachers, carpentry and joinery students and carpentry and joinery craftsmen respectively.

Hypotheses Testing

Table 4: One-way Analysis of Variance (ANOVA) for grooving operation using CNCWMs for carpentry and joinery in TCs

	Sum of Squares	df	Mean Square	f	Significance
Between Groups	.218	3	.218	.597	.444
Within Groups	17.562	956	.366		
Total	17.780	959			

Result: $F(959) = 0.597$, $P = 0.444$. The ANOVA Table 4 above showed the null hypothesis was accepted. This implied that the carpentry and joinery teachers, students and craftsmen in practice are all in the opinion that grooving operation using CNCWMs in carpentry and joinery skills and competencies assessment for TCs in Kano State.

Table 5: One-way Analysis of Variance (ANOVA) for rebating operation using CNCWMs for carpentry and joinery in TCs

	Sum of Squares	df	Mean Square	f	Significance
Between Groups	.2517	3	.258	23.875	.028
Within Groups	15.263	956	.325		
Total	17.780	959			

Result: $F(959) = 23.875$, $P = 0.028$. The ANOVA Table 5 above showed the null hypothesis was rejected. This implied that the carpentry and joinery teachers, students and craftsmen in practice are all in the opinion that rebating operation using CNCWMs in carpentry and joinery skills and competencies assessment for TCs in Kano State.

Table 6: One-way Analysis of Variance (ANOVA) for carving operation using CNCWMs for carpentry and joinery in TCs

	Sum of Squares	df	Mean Square	f	Significance
Between Groups	.2517	3	.258	9.001	.000
Within Groups	15.263	956	.325		
Total	17.780	959			

Result: $F(959) = 23.875$, $P = 0.028$. The ANOVA Table 6 above showed the null hypothesis was rejected. This implied that the carpentry and joinery teachers, students and craftsmen in practice are all in the opinion that carving operation using CNCWMs in carpentry and joinery skills and competencies assessment for TCs in Kano State.

Discussion of Results

The CNCWMs which had become the new trend in woodworking operations had not so far obtained its desired outcomes. Many of the woodworking operational skills and competencies using CNCWMs had failed to enhance the delivery of practical lessons of woodworking operations, such as grooving, rebating and carving others. Carpentry and joinery students graduated from TCs and instead of being work ready using CNCWMs, would display ignorance or lack of experience about the activities that carried-out under their chosen profession in the woodwork occupation, such as furniture craft. This finding corroborates the assertion by Omoh et al. (2019) that the grooving operation using CNCWMs is a means of enhancing relevant skills and competencies for carpentry and joinery teachers and students as well as carpentry and joinery craftsmen. They however recommended that TCs should be actively involved in assisting students in getting organisations where they can seriously carry-out carpentry and joinery using CNCWMs practical, seminars, and where they would be engaged during their rebating operations. CNCWMs had been known all through the years to TCs efforts at making students and fresh TCs carpentry and joinery graduates (craftsmen) to be work ready and immediately employable. It had been noted that inability of carpentry and joinery craftsmen to create jobs and be employable had been attributed to the failure of CNCWMs skills and competencies.

Workshop establishment are to relate their activities to the TCs to enable students upon graduation think out what they are able to create wooden articles using CNCWMs in carpentry and joinery workshops. Students were not been trained to acquire hands-on-the job skills and competencies to provide necessary services that are required in the carpentry and joinery workshops in TCs.

Conclusions

It has become pertinent to note that CNCWMs to note that CNCWMs operational skills and competencies is a way forward to go in enhancing the effective delivery of carpentry and joinery, the components of CNCWMs delivery the grooving, rebating and carving operations. The aspects of student's activities tend to relate job experiences active fields of study so as to attain work ready status to our TCs graduates. This study head proved that more work still has to be done in making furniture using CNCWMs to effectively and efficiently enhance the delivery of grooving, rebating and carving operations.

Recommendations

Consequent on the findings of this study, the following recommendations are made:

5. Furniture craftsmen should be trained and retrain the grooving operation and related operational skills and competencies using CNCWMs in carpentry and joinery workshops.
6. Government should organize regular workshops, seminars and conferences on rebating operation using CNCWMs to suit the carpentry and joinery works efficiently and effectively.
7. Furniture workshops employers (Master Craftsmen) should supervise their craftsmen on carving operation using CNCWMs because is complex operation unlike others woodworking operations.

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ADOPTION OF ARTIFICIAL INTELLIGENCE IN UNIVERSITY LIBRARIES IN NIGERIA. “STRATEGIES AND CHALLENGES”: A REVIEW

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Abstract

Artificial Intelligence (AI) has become a potential transformative technology that can revolutionize library services and engage users, facilitate access, and optimize library functions. The main aim of this review is to assess how artificial intelligence technologies are being adopted in Nigerian university libraries, exploring both the enabling strategies and challenges faced during this process. Objectives are to: identify artificial intelligence tools currently in use in university libraries in Nigeria and their service applications, examine strategic approaches to implementing artificial intelligence, highlight challenges hindering effective adoption and integration of artificial intelligence and propose recommendations that may help to enhance adoption artificial intelligence and its sustainability in university libraries in Nigeria. The study reviewed current literature globally on infrastructural, organizational, and human capacity that enable artificial intelligence adoption and underscores gaps, barriers, and prospects in the adoption curve. Findings shows that ChatGPT is a major AI tool utilized by librarians in Nigeria on a person bases but it has not been embedded in library services due to technology insufficiency, policy vacuum, lack of staff capabilities, as well as financial limitations. The paper ends with strategic suggestions on how to better prepare libraries for artificial intelligence integration to support sustainable transformation of library service.

Keywords: Artificial Intelligence, Adoption, Library Services, Digital Transformation.

Introduction

University libraries are libraries designed to support teaching, research, community development learning and knowledge preservation in every university environment. They are saddled with the responsibility of developing, organizing and providing easy access to timely and accurate information to students, academic staff administrative and support staff and external users. Libraries globally are undergoing significant transformations in response to exponential growth in digital technologies. Alot of this has to do with the 21st century technological advancements, increasingly evolving users' needs, and global events. These changes have redefined library services, emphasizing more on digital integration, inclusivity, and adaptability of the libraries and it teaming users.

Among these digital technologies, Artificial Intelligence (AI) has become a critical innovation, offering tools that support intelligent information retrieval, user personalization, automated cataloguing, and predictive analytics (Russell & Norvig, 2021). However, university libraries often struggle with the challenge of funding which is a necessary factor in the acquisition, upgrade, and maintenance of ICT facilities such as servers, databases, and digital tools present in the libraries. Oyelude and Omotayo (2022), opined that limited financial resources hinder the procurement and upkeep of modern ICT infrastructures in many Nigerian university libraries.

These evolution in ICT demands ongoing training which necessitates capable manpower to help in the utilization of these facilities but many library staff lack adequate skills to utilize these emerging technologies effectively leading to low usage of these technologies in the libraries. This assertion is supported by Ibrahim and Abdulkadir (2023) who also stated that most library personnel lack adequate training to operate advanced ICT tools, which limits the effective use of digital systems in service delivery. Likewise, in many developing countries like Nigeria, unstable and epileptic electricity and unreliable internet access by service providers has been a major setback which have continue to limit ICT usage in university libraries.

Although artificial intelligence and its technologies has significant potential to transform university libraries operations, its adoption in Nigerian universities still remains minimal and largely inadvertent. These gaps are due to infrastructural setbacks, lack of skilled personnels, funding, and policy frameworks hinder the effective integration of this new technology. (Adeleke *et al.*, 2023; Igbo *et al.*, 2025; Odigie, 2024). The aim of the study is to assess how artificial intelligence technologies are being adopted in Nigerian university libraries, exploring both the enabling strategies and challenges faced during this process.

Types Of Artificial Intelligence Tools Used in University Libraries

They are several types Of Artificial Intelligence Tools Used in University Libraries, Odigie (2024) in a qualitative study “exploring the awareness, use and challenges facing the integration of artificial intelligence in Nigerian university libraries” in North-Central Nigeria. The study was carried out using semi-structured interview on reference librarians. Findings from the study revealed that librarians were aware of artificial intelligence and some of it tools personally making use of some of these tools like ChatGPT for literature searches and drafting, but institutional usage was low. The study reported limited use of chatbots/virtual assistants and mostly conventional OPACs without advanced artificial intelligence ranking/recommendation. Infrastructure and training gaps were also a major constraint noted from findings from the study.

Similarly in another review by Adeleke, Olowonirejuaro and Okiki (2023) on adoption of artificial intelligence in Nigerian university libraries: Opportunities and constraints. Survey research design was used for the study. Questionnaire was administered to the sampled institutions. Findings from the study revealed that adoption is mostly confined to OPAC and search engines, with a few libraries experimenting with chatbots or some other third-party discovery tools. Most respondents reported absence of full artificial intelligence systems for cataloguing or recommender services. Financial and skill deficits were noticed as major recurring barriers. Obong *et al.* (2025) in a study of Leveraging Innovative Technologies for Enhanced Access to Digital Resources in Public University Libraries in Abia and Akwa Ibom States, Nigeria, the study adopted the descriptive survey research design. Four specific objectives and four corresponding research questions were designed to guide the study. The instrument for data collection was an observation checklist which assessed the types of innovative technologies available in the libraries and a researcher-developed questionnaire, which addressed the four research questions of the study. Findings of the study revealed that there was high level of awareness of the various innovative technologies, especially Open Access Catalogue (OPAC) and websites among librarians and para-professionals in public Universities in the two states; some of the types of innovative technologies in focus were not available in most of the University libraries, except zoom extra screen magnification, website, OPAC and Radio Frequency Identification (RFID); university libraries

perceived the various innovative technologies as very important for enhanced access to digital resources. The study also established some challenges faced by university libraries in the deployment and use of innovative technologies. Based on the findings, the study recommended among others that university libraries should strive to acquire and leverage various innovative technologies other than zoom extra screen magnification, website OPAC and RFID for enhanced access to digital resources.

Strategies For Adopting Artificial Intelligence

Igbo *et al.*, (2025), in a study “adopting artificial intelligence in academic library services in Nigeria: requirements and challenges”, exploratory research approach was used in conjunction with a comprehensive literature review on the notion of artificial intelligence, its potentials, implications, and modalities of application in libraries; identification of the prerequisites for artificial intelligence adoption and the challenges to its successful implementation in Nigerian libraries. Findings from the study revealed that adoption of artificial intelligence in Nigerian libraries requires the availability of policy documents/frameworks, digital infrastructural facilities, human capital development and expertise as well as generation of data for training in artificial intelligence application and ensuring the security/privacy of data. This study was supported by Odigie (2024) who examined Nigerian university libraries and highlighted strong awareness and usage of artificial intelligence tools (e.g., ChatGPT, Gemini) among reference librarians, but finds usage mainly for personal rather than professional purposes. Key barriers include lack of formal training and infrastructure limitations, a clear signal for the need for targeted capacity-building interventions in the aspect of organizing workshops and seminars. The Association of University Librarians of Nigerian Universities (AULNU) explicitly advocates for structured training programs, including workshops, to foster digital literacy and artificial intelligence readiness among library staff.

The integration of Artificial Intelligence (AI) technologies into academic libraries has brought about significant transformations in information management and user services. In a related article by Joel (2025), that explores the prospects and challenges of artificial intelligence adoption in academic libraries, with a focus on North East Nigeria. The study adopted descriptive survey research design, gathering data from 500 library staff members across three federal universities in the region. Findings from the study revealed a positive outlook on the prospects of artificial intelligence technologies in enhancing library efficiency, user support, data analysis, and resource accessibility. AI has emerged as a transformative force in university libraries, enhancing service delivery and research skills. However, the successful use of AI for library operations depends profoundly on the readiness and training of the library staff. Abiolu and Akinyemi (2025), supported this assertion in a study staff training and the use of artificial intelligence (AI) in University Libraries. The study employed the use of survey research design. The study population was 91, comprising all the librarians (professional librarians) working in nine selected university libraries in Ondo, Osun, and Ekiti States, Southwest Nigeria. Findings from the study revealed that artificial intelligence training, such as introductory training on AI fundamentals, Programming and Coding, evaluation of AI, Conferences and Workshops on AI, and ethical considerations of AI, among others, are required strategies for artificial intelligence adoption in university libraries.

Adeleke *et al.* (2022) assessed Nigeria’s university libraries and found that although many are e-enabled, they are yet to reach full digital maturity, with deficiencies in ICT planning, leadership,

and infrastructure being key barriers. Robust ICT infrastructure is therefore key for supporting artificial intelligence tools such as online public access catalogue (OPAC) upgrades, chatbots, smart cataloguing, and recommendation engines. Artificial Intelligence tools such as chatbots, intelligent cataloguing systems, digital infrastructure upgrades, and staff training programs all require considerable initial investment and ongoing support. Some potential sources of funding which is a major factor that can help keep this project running include: Institutional Budgets, Government Grants, Public–Private Partnerships (PPPs) and International and Donor Agencies.

Challenges of Adopting Artificial Intelligence by Libraries in Nigeria

Adeleke et al., (2024) reported that artificial intelligence adoption in most Nigerian university libraries is still in its infancy stage and is significantly constrained by paucity of funds, lack of requisite skills, and poor infrastructure. These financial limitations make it challenging to afford not just the acquisition of artificial intelligence tools, but also their seamless integration into library operations. Igbo et al. (2025) identified the high cost of establishing artificial intelligence systems encompassing hardware, software, licensing, and support from the parent institution as a major obstacle to its adoption in Nigerian academic libraries. The burden of both initial setup and ongoing maintenance often falls on constrained institutional budgets, further hampering its implementation. In a related study, Igbo et al. (2025) reiterated that one of the major barriers to artificial intelligence adoption in Nigerian academic libraries is a pronounced lack of technical skills among library staff. This includes capabilities in machine learning, programming, and the effective deployment of technologies like chatbots, smart cataloguing, and automated systems. Also, staff fear of job loss as a significant psychological barrier to artificial intelligence adoption were identified. Librarians, especially those engaged in cataloguing and repetitive information management tasks, perceived serious threat to their professional roles with the adoption of artificial intelligence which hinder greatly its integration into the library system. Odigie's study on Nigerian university libraries found that there is high awareness of artificial intelligence tools like ChatGPT among reference librarians, but this has not translated into professional implementation. A key impediment is insufficient infrastructure, including unreliable internet access, which severely restricts the integration of artificial intelligence into library services (Odigie, 2024). Aminu (2024), in a study of federal university libraries in Nigeria revealed that most artificial intelligence implementations are limited to basic tools such as social media, OPAC systems, search engines, and security scanners. More advanced artificial intelligence applications, like chatbots, robots, RFID (Radio-Frequency Identification) or smart cataloguing, remain largely unadopted, pointing to a low level of strategic artificial intelligence integration in library operations.

Recommendations

1. The university and library management should provide continuous training and retraining programs for staff. This can be done by organizing seminars/workshops for staff concerned.
2. The university and library management should work on improving library infrastructure, power supply and internet connectivity.
3. Budget is a major setback in most libraries of today. They most times lack the financial backing to execute their duties diligently. University and library management should endeavor to increase budgetary allocation for ICT systems and tools.

4. Library management should establish ethical and governance framework to ensure fair use and utilization of the system when fully implemented.
5. The university management can incorporate artificial intelligence literacy programs into library and information science curricula.

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ONTOLOGY ALIGNMENT FOR MATCHED DOMAIN BASED ONTOLOGIES: A PROPOSED FRAMEWORK

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Abstract

Ontology alignment is critical in semantic heterogeneity and providing interoperability of various knowledge representation systems. In the agricultural sector, and in fertilizer-specific application in particular, independently created ontologies often vary in structure, vocabulary, and granularity, impeding effective data integration and reuse. A hybrid fertilizer specific matched-domain ontology alignment framework is proposed in this paper to improve semantic consistency and ensure interoperability. Three ontologies were used, MaCOnto, Fertilizer Ontology, and AGRO, based on coverage of fertilizer-specific concepts. Lexical matching, structural matching, and rule-based mapping are combined in the proposed framework and reinforced with semantic enrichment by external resources like WordNet, Word2Vec, and BabelNet. preprocessing step maintains format consistency and normalizes languages, followed by the systematic alignment section of classes, object properties, data properties, and individuals. The output of the aligned ontology provides a single, semantically consistent knowledge base amenable to use in agricultural decision-making support, research, and policy development. Performance measures are precision, recall, F-measure, scalability, and computational efficiency. Hence overcoming the issues of inconsistent use of terminology and inter-lingual variation, this approach tends to provides a workKAPle scalability adaptable to further domain-specific applications and enhances the management of agricultural data to support complex, data-based applications in precision agriculture.

Keywords: *Ontology alignment, fertilizer ontology, AGRO, ontology frameworks, MaCOnto.*

Introduction

Ontology is a data modeling technique for structured data repository which is premised on the collection of concepts with their semantic relationships and constraints on domain (Aminu et al., 2020). Its rich semantic data model provides a common understanding of a given domain by defining a shared vocabulary, which is formally specified in a machine-processable format (Osman et al., 2021). In addressing semantic techniques in thematic research issues in various areas such as information systems, knowledge management, and natural language processing, given its integral capability of decidable Description Logic-based languages with their standardized serializations, such as the Web Ontology Language (OWL) family (Dawson & Keet, 2024).

According to Gruber, (1993), that define ontology as an “explicit and formal specification of a shared conceptualization”. Aminu et al., (2022) research in MaCOnto also points that the demand for relevant information in a timely manner portrays the significance of knowledge management. One of the major approaches in solving the issues of data heterogeneity on the semantic web, is the alignment of ontology. Ontology alignment is a collection of correspondences among two or more ontologies (Taye M. M., 2023). An ontology is said to be ‘aligned’ when the entities used in one ontology is matched to one or more entities in the other ontology, forming a mapping (Pinto

& Martins, 2000). The heterogeneity of ontologies, which may vary in structures, vocabularies, and assumptions are the primary challenge in ontology alignment or integration. Aminu et al., (2022), suggest the growing volume of agricultural data requires a comprehensive knowledge representation system, but the lack of effective ontology alignment hinders its usability. Similarly, Malik *et al.*, (2021), it is to note that; some of the ontologies were developed independently, leading to inconsistencies in terminology, structure, and granularity across different systems within the same domain. These differences hinder the seamless exchange of information and reduce the efficiency of data-driven decision-making processes. In response to these challenges, the need for a robust ontology alignment and integration framework has become inevitable. Therefore, this research aims to develop a framework for the alignment of matched domain-based ontologies, focusing on addressing the challenges presented by semantic diversity and complexity of three agricultural ontologies obtained from Aminu et al., (2022); Malik *et al.*, (2021); and AGRO from agroportal.com. The research addresses a crucial gap in ontology alignment, specifically in managing complexities related to cross-lingual and cross-cultural differences, it also aims to tackle the challenges identified in previous studies, which highlight the growing volume of agricultural data and the need for a comprehensive knowledge representation system.

The objective of the study is to design an ontology alignment framework for matched domain-based fertilizer ontologies and develop the proposed framework to enable seamless integration.

Literature Review

This review critically examines key concepts, methods, challenges, and related work on ontology alignment, with particular emphasis on aligned domain-based ontologies. Ontologies are structured frameworks, representing knowledge within a specific domain and detail the relationships between concepts, terms and entities (Gruber, 1993). Aminu *et al.*, (2022) note, ontology as a top-notch technology which has proven to proffer solution across different knowledge areas.

According to Hu and Qu (2006), Web ontologies written in RDF or OWL play a prominent role in the Semantic Web. The common relationship cardinality of mappings between concepts, relations or instances, here domains were uniformly name as entities of the ontologies which is 1:1. A block is a set of domain entities. A pair of matched blocks from two ontologies in correspondence is unknown as a block mapping and the process of discovering block mappings is refer to as block matching.

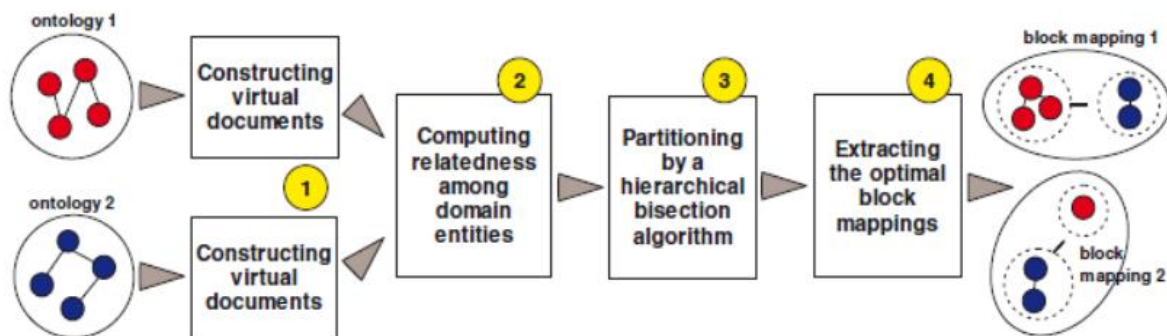


Figure 1: Block mappings between two ontologies Hu and Qu (2006).

Ontology Development

It is actually tedious and time consuming to develop an ontology, which expectedly, requires methodology like any software development. Ontology development, which is an iterative process, enables development from a smaller scale. Testing, evaluation and further expert review are needed for any initial prototype ontology (Safee *et al.*, 2018).

According to Aminu *et al.*, (2020), the creation of Ontology can either be from scratch or reused. Aminu *et al.*, (2022), decision to develop MaCOnTo from scratch was driven by the need for a domain-specific ontology that could adequately represent the knowledge required for maize crop management. However, the authors also emphasize the importance of ontology reuse. Also, Malik *et al.*, (2021), decision to develop the fertilizer ontology from scratch was driven by the lack of existing ontologies that could meet the specific needs of the domain. Developing an ontology from scratch allows for greater customization and ensures that the ontology is precisely tailored to the requirements of the application. If an ontology that is suitable to be reused is not found, then one must build it from scratch using one of the available ontologies building methodologies (Pinto & Martins, 2000).

Design of an Ontology Alignment Framework for Matched Domain-Based Ontologies

The key component of this research is the establishment of an ontology alignment framework and the goal is to overcome the difficulties that may arise when the ontologies, pertaining to fertilizers are integrated. In order to achieve this, the following are considered.

Collection and Analysis of Existing Ontologies

The choice of MaCOnTo, Fertilizer Ontology (FertOnt) and AGRO (AGROVOC) was based on their relevance to agricultural data representation. MaCOnTo provides a structured ontology for maize crop management, including fertilizers, soil, and irrigation. The Fertilizer Ontology (FertOnt), offers a detailed classification on fertilizers, while AGRO (AGROVOC) is a well-established ontology for agronomic concepts. These ontologies provide a comprehensive dataset for testing the proposed framework's effectiveness.

Development of the Ontology Alignment Framework

The proposed ontology alignment, selects the best suitable algorithm for fertilizer ontologies based on their accuracy requirements and scalability features and their capability to handle domain-specific complexities. The method optimizes alignment through the integration of WordNet for lexical and semantic relationships with Word2Vec for contextual semantic similarity and BabelNet for multilingual and conceptual coverage. The methodology begins with preprocessing steps which perform standardization and normalization of ontologies before applying lexical and structural and rule-based matching for achieving consistent mappings. The expert-based hybrid system creates a single domain-specific fertilizer ontology that achieves maximum semantic accuracy along with interoperability and agricultural data integration.

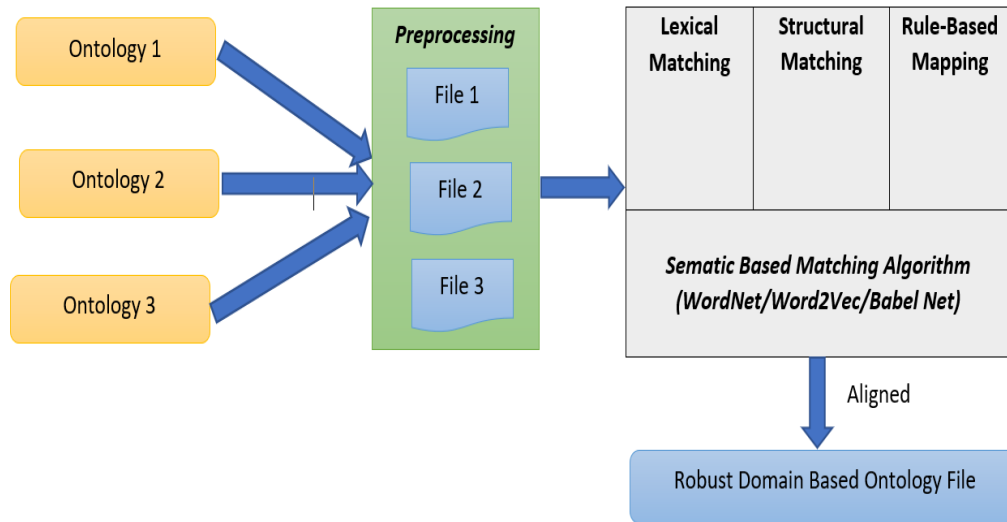


Figure 3: Conceptual Framework of the Proposed Ontology Alignment

Figure 3, aligns various agricultural ontologies that is fertilizer-based within a systematic sequence. After three interrelated but distinct ontologies are selected, preprocessing ensures format compatibility and normalizes languages to reduce linguistic and structural disparities. A hybrid alignment strategy follows and combines the following together: linguistic matching (synonym identification, lexical similarity, stemming, and lemmatization), structural matching (hierarchical and relational correspondences), and rule-based mapping (customized based on prefixes, suffixes, and taxonomic relationships) in a unified framework. Semantic matching follows by utilizing reasoning techniques and external tools like WordNet, Word2Vec, and BabelNet to ensure consistency in the meaning of the concepts throughout the ontologies. Finally, a fertilizer-domain specific aligned ontology is the result, which is optimized for fertilizer knowledge integration.

Table 1: Algorithmic Design for the Proposed Ontology Alignment

Input: MaCOnTo (Mo), Fertilizer Ontology (Fo), AGRO(Ao)

Parameters: Rule-based mapping, lexical matching, structural matching, semantic matching, external resources: WordNet (Wn), Word2Vec (Wv), and BabelNet (Bn), Class (C), ObjectProperty (Op), DataProperty (Dp), Individual (I), last number of class, property, individual (n), Fertilizer Ontology (Fo)

Output: Alignment of Fertilizer Ontology

```

1: Input Mo, Fo, Ao
2: Convert Mo, Fo, Ao To OWL
3: Standardize Mo, Fo, Ao into Triple // using middle level approach
4: Align Classes of Mo, Fo, Ao
5: Align ObjectProperty of Mo, Fo, Ao
6: Align DataProperty of Mo, Fo, Ao
7: Align Individuals of Mo, Fo, Ao
8: While C <= n
9:   Check C of Mo  $\equiv$  C of Fo,  $\equiv$  C of Ao // using WordNet, Word2Vec, and BabelNet
10:   If C1 $\equiv$ C2 $\equiv$ C3 Then
11:     Print C of Aligned Fo Else
12:     GoTo 9
13:   While Op <= n
14:     Check Op of Mo  $\equiv$  Op of Fo,  $\equiv$  Op of Ao // using WordNet, Word2Vec, and BabelNet
15:     If Op1 $\equiv$ Op2 $\equiv$ Op3 Then
16:       Print Op of Aligned Fo Else
17:       GoTo 14
18:     EndIf
19:   EndLoop
20:   While Dp <= n
21:     Check Dp of Mo  $\equiv$  Dp of Fo,  $\equiv$  Dp of Ao // using WordNet, Word2Vec, and BabelNet
22:     If Dp1 $\equiv$ Dp2 $\equiv$ Dp3 Then
23:       Print Dp of Aligned Fo Else
24:       GoTo 21
25:     EndIf
26:   EndLoop
27:   While I <= n
28:     Check I of Mo  $\equiv$  I of Fo,  $\equiv$  I of Ao // using WordNet, Word2Vec, and BabelNet
29:     If I1 $\equiv$ I2 $\equiv$ I3 Then
30:       Print I of Aligned Fo Else
31:       GoTo 28
32:     EndIf
33:   EndLoop
34: EndLoop

```

The algorithm in Table 1, takes three different OWL-formatted ontologies (MacOnto, Fertilizer Ontology (FertOnt) and AGRO (AGROVOC)), and converts them into triples Classes (C), Properties [Object Property (Op) and Data Property (Dp)], and Individuals (I) using a middle-level approach. It aligns these elements across the three ontologies by iteratively comparing each category (C, Op, Dp, I) using WordNet, Word2Vec, and BabelNet. For each type, the algorithm checks equivalence across the three ontologies in a while loop; if a match is found, the aligned element is recorded; otherwise, the process repeats until all alignments meet the equivalence conditions, ensuring a unified and semantically consistent Fertilizer Ontology.

Evaluation of the Developed Ontology Alignment Framework

This addresses conceptualization of the framework by utilizing Word2Vec, WordNet, and BabelNet for better semantic alignment. To demonstrate the efficiency of the framework in aligning fertilizer ontologies, it will in the future be tested on agricultural ontologies in terms of accuracy, precision, recall, scalability, and computationally efficiency.

Performance metrics

Several common performance indicators which are generally used in the ontology alignment community to evaluate the efficacy of the built ontology alignment framework. Such as the use of Precision to calculate the ratio of true-positive matches to the overall predicted matches, valuable in avoiding false positives with specific applications, Recall measures the proportion of actual matches found, ensuring completeness in alignment and reducing missed matches, F-measure (F1 score) strikes a balance between precision and recall and provides a balanced overall performance measure, Computational Efficiency Measures time, memory, and processor resources needed for alignment completion, particularly for large datasets and Scalability measures the scalability of the framework in preserving accuracy and efficiency in dealing with larger and more complex ontologies.

Dataset Selection for Evaluation

In order to assess the effectiveness of the created framework, a selection of actual agricultural ontologies is made. The ontologies come from openly accessible repositories such as GitHub, and AgroPortal.

Conclusion

This research points the importance of ontology alignment in resolving semantic heterogeneity in the agricultural sector, in specific, where independently developed and heterogeneous ontologies are often barriers for integrating and rendering such information and things interoperable. With focus on fertilizer ontologies. The proposed ontology alignment approach combines lexical methods, structural, semantic, and rule-based methods and augments with external resources like WordNet, Word2Vec, and BabelNet for achieving comprehensive semantic accuracy over multiple heterogeneous ontologies.

Through its hybrid approach, the framework systematically preprocesses, normalizes, and aligns concepts, properties, and individuals from MaCOnTo, Fertilizer Ontology (FertOnt), and AGRO (AGROVOC), producing a robust unified fertilizer-domain ontology that is semantically consistent and interoperable. The framework considers performance evaluation with the use of standard measures of ontology alignment like precision, recall, F-measure, and scalability and efficiency in the use of computations. When fully deployed and tested on real-world agricultural ontologies, the framework can significantly facilitate improved knowledge sharing, enable comprehensive decision-making, and aid in complex agricultural applications. Most importantly, it not only addresses the significant gap in fertilizer ontology alignment but also provides a methodological basis transferable to other domain-specific ontology integration problems.

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IMPACT OF ARTIFICIAL INTELLIGENCE (AI) IN THE 21ST CENTURY GLOBAL WORLD

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Abstract

This study examines the global and continental impacts of Artificial Intelligence (AI) from 2014 to 2024, synthesizing evidence across healthcare, education, agriculture, finance, governance, and defense. Employing a systematic review and meta-synthesis of peer-reviewed articles, institutional reports, and policy documents, we thematically analyzed 20 real-world studies. Key findings reveal AI's capacity to match expert clinicians in diagnostic imaging (AUC up to 0.97), boost student performance by 0.37 SD via adaptive tutors, increase credit access by 23%, and improve crop yields by 40% through precision agriculture. Tele-ultrasound deployments reduced stillbirths by 78%, while autonomous drones and smart mobility systems enhanced operational efficiency but raised ethical concerns. Despite these gains, challenges persist in training, infrastructure, algorithmic transparency, and governance. We recommend targeted investments in AI education, robust ethical frameworks, infrastructure upgrades, and international research partnerships to ensure inclusive, responsible AI adoption.

Keywords: Adaptive Learning, AI Governance, Artificial Intelligence, Autonomous Weapons, Diagnostic Imaging, Digital Health Equity, Explainable AI, Machine Learning, Precision Agriculture and Smart Mobility

Introduction

Over the last decade, Artificial Intelligence (AI) has shifted from a theoretical concept to a practical force powering innovation globally. AI is defined as the ability of machines to simulate human intelligence through learning algorithms, AI is now central to speech processing, autonomous systems, and intelligent recommendations. Between 2014 and 2022, global private investment in AI surged from \$12.75 billion to \$91.9 billion, a testament to its growing importance (Stanford AI Index, 2023). Major technology firms like Google, Amazon, and Microsoft have spearheaded developments in this area, while countries including China, the USA, and Canada have established national strategies emphasizing AI research, ethics, and skill development (OECD, 2021). The real-world impact of Artificial Intelligence (AI) has expanded across sectors, with healthcare, education, and agriculture experiencing transformative changes. In clinical settings, AI systems are enhancing diagnosis and treatment planning; Esteva et al. (2018) found that AI matched expert dermatologists in identifying skin cancer. During the COVID-19 pandemic, nations like Singapore and South Korea applied AI-based models to trace and contain outbreaks effectively (Chen et al., 2020). In classrooms, personalized learning systems such as Squirrel AI in China and Carnegie Learning in the USA increased learning outcomes (Zawacki-Richter et al., 2019). Simultaneously, AI-driven tools have improved food security in East Africa by optimizing pest control and forecasting yields (IFPRI, 2021).

While the technological advancements are commendable, growing concerns about fairness, accessibility, and governance have emerged. Studies by the Artificial Intelligence (AI) Now Institute (2018, 2021) highlight how AI-based decision tools can embed racial and social bias, especially in policing and facial recognition. Eubanks (2018) similarly argues that automated systems in social services often reinforce inequality among marginalized populations. The digital divide remains a critical issue; while nations like Finland and South Korea integrate AI into policy and education, Sub-Saharan countries like Nigeria lag behind due to infrastructural and technical limitations (UNESCO, 2021). The rise of generative AI tools, including ChatGPT and Google Bard, has further deepened ethical debates on misinformation, content ownership, and algorithmic responsibility prompting regulatory action such as the EU AI Act (2023) and UNESCO's global AI ethics framework.

Artificial Intelligence (AI) stands out as one of the most revolutionary forces shaping today's global society. Over the past decade, its influence has steadily expanded, changing how people live, work, and relate to their environments. From healthcare and education to agriculture, transportation, and government, AI is actively reshaping institutions and systems around the world. As nations strive for digital transformation, AI serves as a catalyst for growth and innovation while also raising new ethical, social, and regulatory challenges. The real-world impact of AI can be understood by examining how it has evolved across key sectors and regions in recent years.

In healthcare, AI has improved how diseases are diagnosed, tracked, and managed. Algorithms developed in the United States, for instance, now support radiologists by identifying signs of illnesses like cancer with levels of accuracy comparable to human experts (Topol, 2019). During the COVID-19 outbreak, countries such as South Korea and Singapore used AI systems for real-time monitoring and outbreak forecasting, helping health officials respond more quickly and effectively (Chen et al., 2020). In underserved regions, AI-based mobile apps and diagnostic tools are helping bridge healthcare access gaps, showing that AI is not only enhancing clinical practice but also promoting healthcare equity.

Artificial Intelligence has become a game changer in the field of education. It supports adaptive learning platforms that adjust to students' individual progress, helping teachers deliver tailored instruction. Solutions such as Squirrel AI in China and Carnegie Learning in the U.S. have demonstrated success in boosting academic performance and closing achievement gaps between students from different backgrounds (Zawacki-Richter *et al.*, 2019). AI also assists educators by automating administrative tasks like grading, lesson planning, and content curation especially useful in digital and hybrid classrooms. These advancements signal a future where AI can help improve teaching effectiveness and make learning more accessible to all.

As industries digitize their operations, AI is reshaping global labor markets. According to the World Economic Forum (2020), around 85 million jobs may be displaced by AI and automation by 2025, yet the same technologies are expected to generate about 97 million new positions, mainly in digital fields. In sectors like manufacturing, logistics, and finance, AI-driven systems improve performance through automation, predictive analytics, and real-time monitoring. However, this transformation also brings challenges, particularly in workforce readiness and skills alignment. Many workers now require retraining to remain relevant in a technology-driven economy, highlighting the need for coordinated policy responses and lifelong learning initiatives.

AI has introduced new possibilities for agriculture by enabling more precise and efficient farming techniques. Technologies that interpret soil data, weather patterns, and pest behavior allow farmers to make better decisions and increase productivity. In East Africa, tools such as PlantVillage Nuru have empowered small-scale farmers to detect crop diseases early, contributing to improved maize yields and food stability (IFPRI, 2021). As climate change continues to impact agricultural productivity, AI is offering practical solutions for sustainable food systems especially in regions where traditional farming practices are vulnerable to environmental shocks.

AI is helping cities become smarter by optimizing transportation networks, energy use, and public services. In urban centers like Helsinki and Singapore, AI-based systems are used to regulate traffic flow and reduce commute times, contributing to lower carbon emissions and a cleaner environment (McKinsey, 2022). These innovations are also evident in autonomous transport, intelligent waste management, and building automation. With urban populations growing rapidly, AI offers tools for city planners and governments to build more livable, efficient, and sustainable cities, where technology plays a central role in solving everyday challenges.

Public institutions are increasingly integrating AI to streamline services and support data-driven policymaking. From tax fraud detection and biometric ID verification to automated responses in health or education portals, AI is enhancing how citizens interact with governments. However, these developments raise significant concerns about civil liberties. The use of facial recognition in law enforcement, for example, has sparked debates about surveillance, accuracy, and human rights. The challenge lies in harnessing AI's capabilities without compromising transparency, privacy, or accountability especially in democratic societies where public trust is paramount.

Alongside its opportunities, AI raises deep ethical questions about fairness, transparency, and control. Systems trained on biased data can unintentionally discriminate against certain groups, particularly in hiring, credit scoring, and policing. The AI Now Institute (2021) warns that without oversight, AI tools risk perpetuating systemic inequalities. Moreover, the rise of generative AI models such as ChatGPT, DALL·E, and Bard has led to growing concerns about misinformation, content ownership, and digital exploitation. In response, international bodies like UNESCO and the European Union have proposed ethical frameworks and legislation to ensure AI development is inclusive, safe, and aligned with human values (UNESCO, 2021; EU AI Act, 2023).

Sectoral Disruption and Socioeconomic Impacts of AI Globally (2014–2024)

Artificial Intelligence (AI) has driven major structural changes across global industries over the last decade, reshaping healthcare, education, employment, and agriculture. In healthcare, AI systems have become essential tools for early disease detection and patient monitoring. A landmark study by Esteva et al. (2018) revealed that AI algorithms could match expert dermatologists in diagnosing skin cancer, demonstrating AI's growing diagnostic reliability. Similarly, during the COVID-19 pandemic, countries such as Singapore and South Korea utilized AI-powered applications to track and predict virus spread, enabling faster public health responses (Chen *et al.*, 2020). These applications underscore how AI is improving healthcare access and preparedness in both advanced and developing nations.

In the education sector, adaptive learning technologies like China's Squirrel AI and the U.S.-based Carnegie Learning have demonstrated strong potential in delivering personalized instruction.

Zawacki-Richter et al. (2019) observed a surge in AI use during the pandemic, particularly in remote learning systems, which broadened access and improved student engagement. In the labor market, the World Economic Forum (2020) forecasted that while 85 million jobs could be lost to automation by 2025, an estimated 97 million would be created, especially in AI and tech-driven fields. AI's role in agriculture is equally promising, with platforms like PlantVillage improving crop yields through data-driven pest detection (IFPRI, 2021).

Methodology

This study adopts a systematic review and meta-synthesis design to examine the global and continental impacts of Artificial Intelligence (AI) between 2014 and 2024. The goal was to synthesize evidence from empirical studies, institutional reports, and policy documents to understand how AI has transformed key sectors healthcare, education, agriculture, employment, and governance across different regions of the world.

Data Sources and Selection Criteria

Relevant peer-reviewed journal articles, white papers, global reports (e.g., from the World Economic Forum, OECD, UNESCO, WHO), and national policy briefs were retrieved from reputable databases such as Scopus, PubMed, Google Scholar, IEEE Xplore, and ScienceDirect. Inclusion criteria were:

- Studies published between 2014 and 2024
- Focus on AI applications and impacts
- Coverage of at least one continent or global trend
- Written in English

Studies without empirical data or lacking geographical relevance were excluded.

Data Analysis Procedure

A thematic analysis approach was employed to identify patterns across regions. Studies were first grouped by continent (Africa, Asia, Europe, North America, South America, and Oceania) and then by sector (healthcare, education, agriculture, economy, etc.). Trends were analyzed to determine the depth, scope, and nature of AI's impact in each context. Meta-synthesis was used to compare and contrast outcomes, identify knowledge gaps, and develop a unified interpretation of global developments in AI.

Ethical Considerations

Since this study is based on secondary data from published materials, there was no direct human involvement. However, due ethical guidelines were followed, including proper citation, academic integrity, and compliance with the fair use policy for scholarly works.

1.5 Result

S/N	Author(s), Year	Continent Country	/ Sector	Research Design Population Sample	/ Key Findings
1	Antwi et al., 2021	Africa (Ghana)	Medical Imaging	Qualitative; Ghanaian radiographers	80.8% believed AI boosts diagnostic accuracy, yet 83.4% were concerned about errors and data risks. Training and

S/N	Author(s), Year	Continent Country	/ Sector	Research Design Population Sample	/ Key Findings
					infrastructure remain critical needs.
2	Mst Rafia Islam & Wasi, 2024	Global & context referenced)	Military warfare (Israel AI Targeting / Ethics	Theoretical framework; case application	Proposes a 3-stage ethical framework (design, deployment, evaluation) for military AI; emphasizes compliance with international humanitarian law amid autonomous weapons deployment in contexts like Gaza.
3	Akogo et al., 2022	Africa/US/Vietnam	Medical Imaging	Clinical eval.; cross-regional datasets (n = 10,000+)	AI outperformed human radiologists in detecting cardiomegaly and pleural effusion (AUC 0.90–0.97), offering scalable low-cost diagnostic tools in low-resource settings.
5	Johnny & Ifemide, 2024	Africa (Nigeria)	Fintech / Credit Scoring	Empirical study; banks + fintech; n = 500+ loans	ML models increased credit access for underserved Nigerians by 23%, reduced defaults by ~15%, though algorithmic transparency remained limited.
7	Adeoye & World Bank, 2025	Africa (Nigeria)	Education	Pilot study; AI chatbot across 25 schools	WhatsApp-based AI tutor improved student math performance in low-bandwidth schools by 0.37 SD. Teachers reported better classroom engagement and learning autonomy.
8	Albanese et al., 2021	Global	Agriculture	Experimental; AI edge detection in fields	DNN-enabled pest detection helped farmers improve yield prediction accuracy and target interventions, offering scalable solutions in smallholder and climate-vulnerable regions.

S/N	Author(s), Year	Continent Country	/ Sector	Research Design Population Sample	/ Key Findings
9	Zhang et al., 2023	Asia (China)	Agriculture	Field trials; aphid detection in 3 provinces	Deep learning model achieved >90% accuracy in wild aphid detection, helping control pest outbreaks and reduce overuse of chemical pesticides.
10	Batz et al., 2025	Global	Smart Agriculture	Remote sensing; multisite trials in Brazil, India	AI integrated with satellites enabled early pest forecasts; predicted outbreaks with 85% accuracy, improving agricultural preparedness and sustainability.
11	Jemal et al., 2024	Africa (Ethiopia)	Maternal Health	Pilot; 10 rural clinics; 800+ women	Tele-ultrasound powered by AI improved access to prenatal imaging; early complication detection rose by 24%, especially in underserved areas.
12	Naz et al., 2025	Global South	Maternal Health	Meta-analysis; 15 studies	AI for gestational age estimation improved accuracy across LMICs. Meta-review showed AI models outperform human estimates by 9% in precision.
13	Tuuli & Prieto, 2024	Global	Obstetric Imaging	Review of resource-limited AI deployments	AI-enhanced point-of-care ultrasound showed potential in real-time diagnostics and triage, but required local capacity-building for scaling.
14	Science Africa, 2024	Africa (Sierra Leone)	(Sierra) Maternal Health	Field report; 12 clinics	Portable AI ultrasound tools reduced stillbirths by 78%, improved midwife decision-making in rural Sierra Leone via real-time alerts and feedback loops.
15	Strielkowski, 2024	Global	Education	Case synthesis; 4 adaptive learning platforms	AI-enhanced platforms improved retention and participation in remote settings. Highlighted as key to post-

S/N	Author(s), Year	Continent Country	/ Sector	Research Design Population Sample	/ Key Findings
					COVID education transformation.
16	Demajo et al., 2020	Europe	Fintech Explainable AI	Theoretical model; simulation	Proposed XAI techniques helped demystify black-box credit scoring algorithms, supporting ethical fintech development in European lending ecosystems.
17	Esteva et al., 2018	North America (USA)	Healthcare	CNN model vs. 21 dermatologists	Deep learning matched expert dermatologists in skin cancer diagnosis with 91% accuracy, showing scalable diagnostic potential in primary healthcare.
18	Chen et al., 2020	Asia (Singapore/Korea)	Public Health	COVID app review; national datasets	AI-driven contact tracing apps reduced infection peaks; helped predict outbreaks 7 days earlier than traditional models.
19	McKinsey & Company, 2023	Global Cities	Urban Smart Mobility	Analytical review of infrastructure innovations across 25 global cities	Smart mobility can reduce congestion and emissions; case studies show digital systems, mobility hubs, and infrastructure integration improve transport efficiency and quality of urban life.
20	AlQershi et al., 2024	Europe (Russia–Ukraine)	Military warfare Autonomous Drones	Secondary analysis; open-source conflict data ((hybrid warfare report))	Both Russian and Ukrainian forces deploy AI-enabled drones and autonomous ground systems, enhancing reconnaissance, target selection, and swarming tactics; raises strategic and ethical concerns in hybrid warfare.

Discussion of findings

Based on the synthesized data from 20 diverse and evidence-based studies, AI has shown transformative power across multiple sectors globally. In healthcare and maternal health, especially across Africa and low-resource countries, AI-enabled diagnostic systems like tele-ultrasound and portable imaging have significantly improved early detection of complications. Jemal *et al.* (2024) and Science Africa (2024) demonstrated notable increases in prenatal care access and a reduction in stillbirth rates by up to 78% in rural areas. Esteva *et al.* (2018) further affirmed AI's diagnostic power by showing dermatologist-level accuracy in skin cancer detection. These findings confirm that AI can close healthcare gaps where medical expertise is scarce, particularly in maternal health and imaging.

In the education and fintech sectors, studies conducted in Nigeria and globally reflect AI's positive impact on learning outcomes and financial inclusion. Adeoye & World Bank (2025) revealed that WhatsApp-based AI tutors improved math performance in low-bandwidth Nigerian schools, while Strielkowski (2024) highlighted increased participation through adaptive platforms. In the financial sector, Johnny & Ifemide (2024) reported that AI-based credit scoring increased loan approvals by 23% in Nigeria, with reduced defaults, though transparency remains a concern. Complementarily, Demajo *et al.* (2020) introduced explainable AI (XAI) techniques to address ethical concerns in algorithm-based lending.

Lastly, the integration of AI in military warfare and smart mobility raises both innovation and ethical questions. AlQershi *et al.* (2024) and Mst Rafia Islam & Wasi (2024) emphasized the ethical complexity of deploying autonomous drones and targeting systems in hybrid warfare. Meanwhile, McKinsey & Company (2023) showed that smart mobility applications such as AI-driven traffic management and infrastructure coordination are helping cities worldwide reduce emissions and enhance commuter experience. Together, these studies reflect the global depth and multidisciplinary relevance of AI's evolving impact.

Conclusion

The collected evidence confirms that Artificial Intelligence is no longer a futuristic concept but a transformative force actively reshaping key global sector. From healthcare and education to agriculture, finance, warfare, and smart mobility, AI is improving service delivery, accuracy, and efficiency. Particularly in low-resource regions like sub-Saharan Africa, AI offers scalable, cost-effective solutions that close developmental gaps. However, ethical concerns, skill shortages, and governance issues must be addressed to ensure AI's benefits are inclusive, sustainable, and globally equitable.

Recommendations

1. Invest in AI education and digital literacy programs to build a skilled, future-ready workforce.
2. Develop transparent AI governance frameworks ensuring ethical deployment and public trust across sectors.
3. Prioritize infrastructure upgrades in underserved regions to enable equitable AI integration and access.

4. Foster global research collaborations to ensure inclusive innovation and culturally relevant AI solutions.

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TRANSFORMING TECHNICAL VOCATIONAL EDUCATION AND TRAINING THROUGH ARTIFICIAL INTELLIGENCE FOR BUILDING A SKILLED AND INNOVATIVE WORKFORCE IN NIGERIA

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Abstract

Technical Vocational Education and Training (TVET) is universally recognized for its role in preparing individuals for dynamic engagement in occupations of useful value and an effective source for building skilled and innovative workforce in Nigeria. Therefore, this paper focused on transforming TVET through Artificial Intelligence (AI) for building skilled and innovative workforce in Nigeria. The concepts of Technical Vocational Education and Training (TVET), Artificial Intelligence (AI), skilled and innovative workforce were carefully discussed. It also examined the benefits of quality TVET and the challenges facing it in Nigeria. Also, the paper discussed the applications of AI in TVET, its benefits and challenges. The paper concluded that AI can improve TVET by enhancing skill development and aligning training programmes with industry needs. Integrating AI into TVET offers a transformative approach to addressing Nigerian educational challenges. By leveraging AI, TVET sector can improve its quality, align with global standards, and contribute to sustainable development. The paper recommended among others that the Federal Government of Nigeria and private sectors should collaborate to invest in AI tools and training programs to support TVET institutions. It was also recommended that TVET educators should be trained regularly to improve their technical expertise in AI and as well keep up-to-date with recent technological innovations.

Keywords: *Technical and Vocational Education and Training (TVET), Artificial intelligence (AI), Skilled and Innovative Workforce*

Introduction

The aim of Technical Vocational Education and Training (TVET) is to provide individuals with the skills and knowledge required to succeed in their chosen career, and to help address any skills gaps in the job market. It plays a crucial role in equipping individuals with the skills and knowledge needed for employment and entrepreneurship, contributing to economic development and poverty alleviation. Kwami (2024) asserted that TVET is a vital tool for individual empowerment, economic growth, and social development, playing a crucial role in preparing individuals for the challenges and opportunities of the modern world. It also fosters a culture of innovation and self-reliance, addressing the skills gap in various industries.

TVET serves as an indispensable framework which prepares individuals to succeed in the universally developing industry workforce. It is an important component of education recognised globally with the aim of improving economic and social development sectors. TVET is crucial in the development of skilled and innovative workforce, without which no country can develop its economy and become competitive. TVET educates learners to acquire knowledge and skills relevant to certain job sector, therefore increasing their chances in the labour market (UNESCO,

2021). It is useful in filling the skills gap in the labour market, eradicating unemployment and promoting inclusion for the less privileged in society (Muhammad et al., 2025).

The emergence of the fourth industrial revolution characterised with technological revolutions have influenced life culture globally. The present time demands the highest level of technological skills united with extensive expertise because industries now lean toward knowledge-based economics while undergoing digital transformation (Gedeon, 2021). In this age of technological advancement, incorporation of artificial intelligence (AI) is a challenge that offers the potential of transforming TVET programmes. In this regard, this paper examined the following concepts;

- Technical Vocational Education and Training (TVET)
- Artificial Intelligence (AI) in TVET
- Skilled and Innovative Workforce
- Benefits of Quality TVET
- Challenges Facing TVET in Nigeria
- Applications of AI in TVET, its Benefits and Challenges

Technical Vocational Education and Training (TVET)

TVET can be defined as instruction and training intended to provide individuals with the information, expertise, abilities, and/or competencies needed for specific jobs or, more generally, for the labour market (Enamudu et al., 2024). It is education, training, and skill development for a variety of professions, industries, services, and means of subsistence. TVET is the form of education that comprises of the training in skills necessary for gainful employment as well as acquisition of basic educational foundation in both sciences, applied sciences and humanity, all aimed at developing individuals with the right attitude to work and the competency necessary to compete positively in a global society (Obidile, 2018).

The Federal Republic of Nigeria [FRN] (2013) in the National Policy on Education described TVET as a comprehensive term referring to those aspects of the educational process involving, in addition to general education, the study of technologies and related sciences, and the acquisition of practical skills, attitudes, understanding and knowledge relating to occupations in various sectors of economic and social life. The policy further stated the objectives of TVET to include: providing training for manpower development in applied sciences, technology and business particularly at craft, advanced craft and technical levels; providing technical knowledge and vocational skills necessary for agricultural, commercial and economic development; and give training and impart the necessary skills to individual who shall be self-reliant economically.

Akamobi (2022) reported that TVET in Nigeria is a major producer of technicians, technologist and engineers that are absorbed in the industries and the informal sector of employment. It comprises of the formal, informal and non-formal system. The formal system is obtainable in the universities, polytechnics monotechnics, colleges of education (technical), technical colleges and other specialized institutions like vocational enterprise institutions among others. While the non-formal TVET are those programmes designed, run and managed by private and public organizations for the purpose of addressing specific needs. TVET programmes at all these levels aims to provide adequate and appropriate skilled workforce through practical training and work experience so that they can respond and adapt to changes occurring in their communities as well as become catalyst for community change (Ntegwung & Njoku, 2022). This means that TVET

institutions can respond to the different training needs of learners from different socio-economic and academic backgrounds and prepare them for gainful employment and sustainable livelihood. Consequently, TVET can be a powerful tool for supporting economic growth and development, both at the individual and community level.

Quality TVET ensures that learners acquire relevant, up-to-date skills aligned with labour market demands and global best practices. It must meet the current and future needs of learners, industries, and society, preparing individuals for meaningful employment and lifelong learning. Quality TVET should integrate technical knowledge, practical skills, and core competencies such as problem-solving, communication, and adaptability (UNESCO, 2021). TVET must be responsive to economic trends, technological advancements, and local labour market dynamics to remain relevant and effective. The emphasis is on hands-on training and theoretical knowledge, ensuring that graduates can meet industry standards and contribute to economic development. Thus, TVET students are expected to be fully equipped to face realities of the world of work and as well have the ability to solve complex challenges in the industries. TVET should abreast latest global innovations like artificial intelligence.

Artificial Intelligence (AI) in TVET

Artificial intelligence (AI) is one of the products of technology snowballing in today's digital era. It refers to the ability of machines to perform tasks that typically require human intelligence. This includes capabilities like learning, problem-solving, decision-making, perception, and language understanding. Essentially, AI aims to create systems that can impersonate and surpass human cognitive functions. AI is a machine-based system that can make decisions, recommendations, or predictions for a given set of human-defined objectives (Ndudi & Chidi, 2025). AI is a trending concept that is currently impacting every industry in the world as it has been applied in several sectors including education, health, and agriculture. Olojuolawe (2024) describes AI as systems that display intelligent behaviour by analysing their environment and taking actions with some degrees of autonomy to achieve specific goals.

AI has emerged as a transformative technology with the potential to transform various sectors, including education. In particular, AI holds significant relevance and importance in the field of TVET. In recent years, the integration of AI technologies into various aspects of human resource management has gained substantial attention (Matteo & Marco, 2024). This trend is particularly pronounced in the realm of education. AI can significantly enhance TVET by personalizing learning, improving feedback, and aligning training with real-time labour market needs. AI-powered tools can create customized learning experiences, offer instant feedback on practical skills, and adapt to individual student needs, leading to better engagement and improved learning outcomes. Additionally, AI can analyse labour market data to ensure TVET programmes remain relevant and prepare students for future jobs.

As a developing country, Nigeria recognizes the crucial role of TVET in its socio-economic development. The Nigerian TVET Institutions provide training across various disciplines. However, the institutions are faced with challenges such as limited resources, outdated teaching methods, and the need to align vocational programmes with the changing needs of industries (Enamudu, Oladunmoye & Okoye, 2024). In this context, AI offers significant potential to overcome these challenges and improve the quality and effectiveness of TVET. One of the primary

advantages of AI in teaching TVET at the Nigerian Institutions is its ability to personalize the learning experience for students. AI-powered systems can analyse huge amounts of data, including student performance, preferences, and learning patterns. By understanding each student's unique needs, AI can tailor the content, pace, and difficulty level to their individual requirements. This personalization ensures that students receive targeted instruction and support, enabling them to acquire the necessary skills efficiently (Ayeni, *et. al.* 2024).

Also, AI can play a crucial role in providing real-time feedback and assessment in TVET. Quansah (2018) opined that traditional assessment methods in practical fields can be subjective and time-consuming. AI tools, such as computer vision and natural language processing, can analyse student work in real time, providing immediate and objective feedback (Yakkala, 2024). This allows TVET instructors to evaluate students' performance accurately and identify areas for improvement. Students can receive timely feedback, make necessary adjustments, and enhance their learning outcomes. Another important application of AI in TVET is bridging the gap between theoretical knowledge and practical application. Hands-on experience is vital in TVET fields, and AI can facilitate this integration by providing virtual simulations and immersive experiences. According to Thangavel, Sharmila and Sufina (2025), virtual reality (VR) and augmented reality (AR) technologies can create realistic training environments, allowing students to practice skills in a safe and controlled setting. The Nigerian TVET Institutions can leverage AI-powered simulations to enhance the practical training experience and prepare students for real-world work scenarios.

Moreover, AI can contribute to the overall improvement of TVET systems at the Nigerian TVET Institutions. AI can analyse large-scale data sets to identify emerging labour market trends, industry needs, and skill gaps. This data-driven approach enables educators to align TVET programmes with the evolving demands of the labour market, ensuring that students acquire the skills that are in demand. The institutions can provide accurate and up-to-date information about job prospects, required skills, and potential career pathways by integrating AI into career counselling and guidance. This empowers students to make informed decisions about their career choices and enhances their transition from education to employment (Sidhu, *et. al.*, 2024). Therefore, AI can significantly transform TVET by providing numerous benefits and improving the overall learning experience for building skilled and innovative workforce.

Skilled and Innovative Workforce

Skilled and Innovative Workforce is crucial for economic development and competitiveness, requiring continuous growth of employee skills and promoting a culture that encourages creativity and problem-solving. This involves not only formal education and training but also on-the-job learning, mentorship, and access to resources that support innovation. Skilled and innovative workforce refers to a group of employees possessing specific knowledge, training, and experience, coupled with the ability to generate and implement new ideas and solutions (Lewis, 2025). This workforce is key for driving productivity, promoting innovation, and enhancing overall organizational success.

These days, the workforce is quite diverse and covers variety of areas. Along with the development of latest technologies, new professions are becoming demandable, and at the same time obsolete ones are being expunged. Any nation that has unique professionals in various fields, realizes several kinds of economic and social benefits. Madubuko and Nwaka (2024) observed that in

developing nations like Nigeria, the demand for qualified professionals tailored to the needs of the contemporary labour market is growing progressively. Consequently, the mobility of skilled and innovative workforces has become one of the main factors of competition between the nations. Manjo (2024) state that any development-oriented nation needs to base its production and services on individuals who will guarantee nation's long-term success.

Undoubtedly, job creation process in the country is extremely important, however it is more essential to have skilled and innovative workforces. The quality of the workforce plays a key role in promoting civil rights, political and economic stability, reducing criminal and corruption risks, developing sustainable investment and economic policies, enlarging entrepreneurship, innovations and general social prosperity of the nation (Shatakishvili, 2021). This is why lack of skilled and innovative workforce deprives the country plenty of potential opportunities, benefits and advantages. The quality of the workforce depends on important factors such as education, access to training programs, physical activity and health status (Chang, 2024). Therefore, quality TVET and access to training with advanced technologies such as AI can be considered as a capital investment that provides stable and long-term results.

Benefits of Quality TVET

The goals of TVET vary depending on the specific programme and the needs of the local labour market. In general, however, the aim of TVET is to provide students with the skills and knowledge they need to succeed in their chosen career, and to help address any skills gaps in the labour market (Okoth, 2023). Quality TVET offers numerous benefits, including enhanced employability, increased earning potential, and contributions to economic growth. Raphael and Hoseah (2025) disclosed that TVET equips individuals with practical skills, promotes self-reliance, and supports sustainable development. Furthermore, quality TVET ensures a skilled workforce, reduces poverty, and fosters innovation.

Quality TVET help to fill the skills gap in the contemporary labour market. A skills gap is a mismatch between the skills that employers need and the skills that job seekers have. According to Sarin (2019), this can result in a lack of qualified candidates for certain jobs, and can lead to problems for industries that are unable to find the talent they need to grow and thrive. He added that TVET can help address the skills gap by providing students with the practical, relevant skills and training they need to succeed in specific careers. Many TVET programmes are designed in collaboration with local employers, so they can be personalised to meet the specific needs of the labour market. This ensures that students are learning the skills that are most in demand and that they are well-prepared to enter the workforce upon graduation.

In addition to providing relevant skills, TVET also offers a more practical, hands-on approach to learning that can be particularly appealing to some students. Rather than spending years in a classroom learning theory, TVET students have the opportunity to learn through doing, by working on real-world projects and gaining hands-on experience in their chosen field (Rama, 2024). This type of experiential learning can be a valuable complement to traditional academic learning and can help students develop the skills and confidence they need to succeed in their careers.

TVET can provide a wide range of career opportunities. Many high-demand jobs in industries require quality TVET. In addition to the wide range of career opportunities available through

TVET, it can also lead to career advancement and higher earning potential Muslim, *et. al.*, 2023). Many TVET graduates go on to advance in their careers and take on leadership roles within their industries. And because TVET programs are focused on providing students with practical skills, graduates may have a competitive advantage in the labour market. Therefore, TVET can be an excellent choice for individuals who are looking for a direct path to a fulfilling and rewarding career.

In today's rapidly changing labour market, it is more imperative than ever to continuously learn and update your skills. This is especially true in fields that rely on technology and are subject to rapid change, such as artificial intelligence. TVET programme can be an excellent way to facilitate lifelong learning and career development (Jamaludin, *et. al.*, 2023). The authors added that TVET offers ongoing training and professional development opportunities for graduates, so they can stay up-to-date on the latest trends and technologies in their field. This type of continuous learning can help TVET graduates stay competitive in the labour market and advance in their careers. Consequently, TVET can be an excellent choice for individuals who are committed to lifelong learning and career development. TVET also play a vital role in supporting economic growth and development and stimulate local economies by creating jobs directly. Therefore, TVET can be a powerful tool for supporting economic growth and development, both at the individual and community level.

Challenges Facing TVET in Nigeria

In Nigeria, TVET is faced with numerous challenges which make it difficult to reduce abject poverty, hunger and unemployment. The major challenges include inadequate funding, lack of motivation for teachers, inadequate equipment and infrastructure facilities, negative perception of TVET, brain drain and deficient curriculum (Allen, 2020). These challenges hinder the development of skilled manpower and limit the potential of TVET to contribute to Nigeria's economic growth.

Inadequate Funding: The inadequate funding has been a problem in the implementation of quality teaching and learning of TVET in Nigerian. This has caused the turning out of half-baked graduates because there is no fund to build and maintain workshops, laboratories or even purchase training materials and modern tools/equipment. Bello and Muhammad (2021) observed that government lack of commitment and inadequate funding has weakened TVET programmes in Nigeria.

Lack of Motivation for TVET Teachers: Lack of motivation for teachers is a serious problem affecting TVET in Nigeria. Salaries, allowances, entitlements are always paid in arrears but at times they are denied of these entitlements which had resulted in poor attitude to work of some teachers. The teachers go about doing their private businesses instead of concentrating on how to improve teaching and learning in the school, thus rendering vocational trainers ineffective and hampering quality of teaching (Olufayo & Falola, 2020).

Inadequate Equipment and Infrastructural facilities: Majority of the TVET institutions of learning in Nigeria do not have well equipped laboratories, workshops and serviceable infrastructures (Ladan, 2023). Where these exist, they are grossly inadequate, obsolete and in a dilapidated state. TVET laboratories that are seen in various institutions today are eyesores as the

laboratories only have equipment that were provided at the point the departments were established. Oviawe, Omoh and Uwameiye (2019) noted that the classrooms and offices in most of the schools were inadequate in terms of decency, space, ventilation and insulation from heat and further noted that the incinerators and conveniences were not strategically placed. These combined deficiencies constitute a major gap in the quality of input and output in education, thus the non-attainment of the set standards and goals of the TVET programmes.

Negative Perception of TVET: In Nigeria today, too much emphasis is placed on qualifications not minding whether the holder possesses the required knowledge and skill. But in advanced societies TVET graduates are highly regarded. In fact, the value system in those countries depend on the person's skills and knowledge, and not on the stack of academic degrees one has. In the public service, TVET graduates are often discriminated against and their career prospect is limited (Sylvester, 2021).

Brain Drain: Brain drain refers to the movement of TVET educators which are needed for the socio-economic and technological advancement of Nigeria from TVET institutions to other professions (including politics) where they feel will offer them better conditions of service.

Deficient Curriculum: The curriculum of subjects with practical content is generally organized into theoretical classes and laboratory. Students also use the laboratory to develop case examples on their own time. Muoghalu and Ayodeji (2022) revealed that one of the issues confronting the design of appropriate curriculum for TVET is preparing students for the shift from the foodist to ICT paradigm in technology practice. The low pace of industrialization and technological growth in Nigeria can be attributed to the widening gap between science and technology as a result of the inability of TVET to adequately utilize the scientific ideas to promote technology. This suggests the need to review TVET curriculum in Nigeria.

Applications of AI in TVET, its Benefits and Challenges

Artificial Intelligence (AI) has become a transformative force across numerous sectors, including education in general and TVET in particular. AI provides TVET students with specialized education through adaptive teaching which integrates automated administrative processes into TVET. Dinesh and Subhashini (2025) opined that application of AI in TVET increases student engagement and improves learning memorization and workforce readiness through AI-powered learning tools that employ intelligent tutoring systems with virtual simulations supported by machine learning algorithms. AI applications in TVET are diverse, ranging from personalized learning and automated grading to curriculum development and career guidance (Onatere-Ubrurhe & Ubrurhe, 2025). AI can analyze student performance, predict at-risk students, and provide targeted support. It also helps in identifying future labour market trends and developing relevant qualifications.

Personalized Learning and Adaptive Tutoring: AI-powered systems can adapt to individual student learning styles, pace, and needs, providing tailored content and feedback. Yarlagadda (2025) stated that intelligent tutoring systems offer real-time feedback and guidance, helping students learn more effectively. AI can track student progress, identify areas of weakness, and provide targeted interventions.

Automated Tasks and Efficiency: AI can automate tasks like grading multiple-choice and short-answer questions, freeing up teachers' time for more complex tasks. Nwokedi and Nwafor (2024) emphasized that chatbots and virtual assistants can answer common student questions, providing instant support and information. AI can also assist with administrative tasks like financial aid applications and student services.

Curriculum Development and Career Guidance: AI can analyse job market trends and predict future skills needs, informing the development of relevant TVET curriculum. AI-powered tools can provide students with personalized career guidance based on their interests, skills, and career goals (Cheng & Liang, 2023). By analysing data on student performance and job market demands, AI can help TVET institutions create more effective and relevant training programmes.

AI-Driven Competency Assessments: AI can be used to assess student competencies in a more objective and efficient way. This can include automated grading of practical tasks and simulations, as well as more sophisticated assessments of higher-order thinking skills.

Addressing Ethical Considerations: While AI offers numerous benefits, Oman, Siddiqua and Noorain (2024) declared that it is crucial to address ethical concerns such as bias in algorithms, data privacy, and the potential for job displacement. Therefore, it is important to develop clear policies and guidelines for the ethical use of AI in TVET. Training programs for educators and students on AI literacy and responsible AI use are also crucial. The integration of artificial intelligence (AI) into technical and vocational education has the potential of revolutionizing the teaching and learning processes in Nigeria by offering significant advancements in skill development and training efficiency.

Despite these numerous benefits, Silas, Ekong and Akpan (2024) observed that the implementation of AI in TVET faces several key challenges, including inadequate infrastructure, insufficient training for educators and learners, ethical concerns, and financial constraints. Furthermore, the digital divide, data privacy issues, and the need for curriculum restructuring to integrate AI effectively are significant hurdles.

Technological Infrastructure and Access: Ukala and Iheukwumere (2025) revealed that many TVET institutions lack the necessary digital infrastructure, such as reliable internet access, sufficient computing power, and updated hardware, which are crucial for implementing AI-driven learning systems. A significant digital divide exists, with many TVET students and educators lacking access to the technology and resources needed to engage with AI-based learning. The initial investment in hardware, software, and training for AI implementation can be substantial, creating a barrier for many TVET institutions, particularly in developing countries like Nigeria.

Educator and Learner Readiness: Educators may lack the necessary training and skills to effectively integrate AI into their teaching processes or to develop AI-powered learning materials. Joseph, Clement and Shitu (2024) stressed that some educators and learners may be hesitant to adopt new technologies, requiring careful change management strategies and targeted training. Students may also have varying levels of digital literacy, which can impact their ability to effectively utilize AI-driven tools and resources.

Ethical Considerations: The use of AI in education raises concerns about data privacy, particularly the collection and use of student data. It's crucial to establish ethical guidelines and data protection protocols. AI algorithms can reflect existing biases, potentially leading to unfair or discriminatory outcomes in assessments or learning experiences (Eden, Chisom & Adeniyi, 2024). This requires careful monitoring and mitigation strategies. Understanding how AI systems make decisions is crucial for building trust and ensuring fairness.

Curriculum and Assessment: Integrating AI into TVET requires a review and potential restructuring of curricula to ensure alignment with the skills and knowledge needed for the future workforce. Yakkala (2024) stated that AI-powered tools can be used to create more personalized and adaptive assessments, but this requires careful consideration of how to ensure fairness and validity. AI can automate routine tasks, freeing up educators to focus on developing higher-order cognitive skills, such as critical thinking, problem-solving, and creativity.

Socio-Economic Factors: The rapid pace of technological change means that TVET programs need to adapt to ensure graduates have the skills required by the evolving labour market. It is crucial to ensure that AI technologies are accessible to all learners, regardless of their background or socioeconomic status. Sylvester (2021) posited that positive perceptions of TVET are essential for attracting students and ensuring adequate funding for TVET institutions. Addressing these challenges will require a multi-faceted approach, including investment in infrastructure, teacher training, curriculum development, and the establishment of ethical guidelines for AI implementation in TVET.

Conclusion

TVET is a critical component of educational system in Nigeria, offering a pathway to employment, entrepreneurship, and economic development. AI can transform TVET by enabling personalized learning, enhancing skill development, and aligning training programmes with industry demands. Integrating AI in TVET offers a transformative approach to addressing Nigeria's education challenges. By leveraging AI, TVET can improve its quality, align with global standards, and contribute to sustainable development. However, achieving these outcomes requires concerted efforts to address the existing challenges. By focusing on equity, ethical practices, and capacity building, TVET can adopt AI as a medium to bridge skill gaps and prepare skilful learners for the future innovative workforce. By investing in infrastructure, changing societal perceptions, and aligning training with labour market needs, Nigeria can unlock the full potential of TVET.

Recommendations

1. The Federal Governments of Nigeria and private stakeholders should collaborate and invest in AI tools and training programs to support TVET institutions as adequate funding is essential for modernizing facilities, updating curricula, and training instructors.
2. TVET educators should be trained regularly to improve their technical knowledge in AI and as well keep them abreast with recent technological innovations.
3. Policymakers should ensure equitable access to AI technologies across regions and demographics and also formulate policies that prioritize investment in AI for education.

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ARTIFICIAL INTELLIGENCE (AI) POWERED COMPETENCY-BASED TRAINING MODELS FOR INDUSTRIAL TECHNOLOGY SKILLED WORKERS

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Abstract

The way we train skilled workers is undergoing a major shift. Industry 4.0 with its mix of automation, robotics, artificial intelligence, and the Internet of Things demands a workforce that can do more than just follow instructions. Workers now need to think critically, adapt quickly, and keep up with fast-changing technologies. Traditional training models, which are often rigid and content-heavy, simply aren't keeping pace. Competency-Based Education (CBE) offers a different approach. It focuses on whether learners can demonstrate the skills required, not just spend a set number of hours in a classroom. When combined with Artificial Intelligence (AI), this model becomes even more powerful. AI can customize training to fit each learner's pace, assess skills in real time, and ensure that training outcomes match what industries need. This paper explores how AI and CBE can work together to transform industrial workforce training. It draws on case studies from Germany, Singapore, and Nigeria, and discusses both opportunities and challenges ranging from personalization and efficiency to ethical concerns and limited resources. The paper ends with practical recommendations for governments, educators, and industry leaders on how to make this transformation a reality.

Keywords: Artificial Intelligence, Competency-Based Education, Industrial Technology, Workforce Development, Skills

Introduction

Industrial technology education has always been central to building a strong workforce. From construction to advanced manufacturing, workers must know how to operate, maintain, and innovate with complex tools and systems. But today's workplace looks very different from even a decade ago. Industry 4.0 has brought a flood of new technologies: smart factories, interconnected devices, and intelligent machines. Employers now expect workers to not only master technical tasks but also to adapt to rapid changes, think critically, and solve problems in real time.

Unfortunately, many training programs haven't kept up. They remain locked into rigid structures that emphasize theory over practice, or standardized curricula that don't match what industries need. The result leads to; A mismatch between graduates' skills and employers' expectations leading to unemployment, underemployment, and lost productivity.

Competency-Based Education (CBE) is one solution. Unlike traditional models, CBE focuses on skills mastery: learners advance only once they can prove they've mastered a competency. At the same time, Artificial Intelligence is transforming education by enabling personalization, intelligent tutoring, and predictive analytics. If combined, AI and CBE could create training systems that are flexible, adaptive, and directly aligned with industry needs.

This paper explores how such integration might look in industrial technology education, especially in contexts like Nigeria where the demand for skilled workers is urgent.

Statement of the Problem

Traditional training models in industrial education are increasingly out of sync with technological advances. Many programs are rigid and slow to adapt, which leaves graduates with outdated skills. This not only reduces productivity but also contributes to unemployment in industries critical for national growth.

Purpose of the Study

This paper aims to:

1. Explore how AI-powered tools can strengthen CBE models in industrial technology education.
2. Share global case studies and best practices for AI-driven workforce training.

Research Questions

1. How can AI enhance competency-based training models for industrial technology workers?
2. What benefits and challenges come with merging AI and CBE for workforce development?

Significance of the Study

This work is valuable to policymakers, educators, industry leaders, and learners. It highlights how AI and CBE can work together to bridge skill gaps, improve employability, and align education with the realities of Industry 4.0.

Scope of the Study

The paper focuses on how AI can be integrated into competency-based education for industrial technology. While case studies are drawn globally, particular attention is given to Nigeria's workforce context.

Competency-Based Education in Industrial Technology: A Holistic and Balanced Approach in Learning

Competency-Based Education (CBE) has emerged as a major topic of interest in educational research and pedagogical practice in recent times (Paek, Um and Kin, 2021). A competent graduate is one who can apply what they have learnt, thereby, operating independently in various real-world practical contexts in the words of Yip & Smales, (2000). At present, CBE is still in the early stages of implementation in certain disciplines, while in others such as medicine, it already has an extensive history and is supported by numerous studies validating its efficiency according to Brammer and Goodrich (2021).

CBE emphasizes the development and evaluation of specific competencies rather than focusing solely on theoretical knowledge. The primary goal of CBE is to prepare learners and trainees to successfully tackle real-world challenges by focusing on developing skills and aptitudes applicable in various contents (Johnstone and Soares, 2014). This educational approach is tailored and applicable, fostering the growth of practical skills and competencies essential for individuals to achieve their personal and professional objectives.

Unlike traditional education, CBE does not adhere to a standard time framework for class attendance and homework. As a result, students often complete course or even entire programmes in shorter time frame which can reduce costs and make education more accessible as highlighted by Lindsay (2018); Mehall (2019) and Brammer and Goodrich (2021). Learning takes place in modules and given the student-centered approach, thereby, learners progress to the next stage of skill once they have sufficiently mastered the associated competencies (Evans, Landl and Thompson, 2020). Research by Evans, Landl and Thompson (2020) and Chen, Zhung and Li (2022) indicates that CBE can increase motivation and engagement in the learning process and foster critical thinking and analytical skills. Those benefits suggest that the implementation of competency-based training in industrial technology education can contribute significantly to improving the learning experience and the holistic development of students.

CBE has played a pivotal role in the reform of education systems. Reform advocates, policy makers, educators and experts have defined “key competencies” for compulsory education in various ways (Anderson-Levitt and Gardinier, 2021). Numerous countries have adopted competency-based learning in their curricular attempting to align education with the demands of the labour market at the requisites of modern society.

CBE and Workforce Development in Nigeria

Competency-Based Education (CBE) is vital for workforce development in Nigeria because it directly addresses the skills gap between academic curricula and industry needs, fostering an employable, entrepreneurial workforce. CBE is highly effective for Technical and Vocational Education and Training (TVET) by imparting specific measurable and transferable skills that are directly relevant to the modern job market.

In addition, CBE also fosters employability and entrepreneurship by equipping individuals with practical skills and a focus on real-world application. CBE helps create a skilled workforce capable of both gainful employment and entrepreneurship which is crucial for national development. The mastery-based nature of CBE cultivates a culture of continuous learning and adaptably essential for thriving in today’s rapidly changing work environment.

The Role of Artificial Intelligence in Competency-Based Education

Artificial Intelligence (AI) is defined as a system’s capability to correctly interpret external data, learn from these data and use this knowledge to accomplish specific tasks and objectives through flexible adaptation (Kaplan and Haenlein, 2019). Consequently, Akgum and Greenhow, (2022) affirmed that these systems can think and act human like, employing advanced algorithms and intricate mathematical models to achieve specific aims.

One of AI’s remarkable facets in education according to Chen. Chen and Lin, (2020) and Peters et al., (2023) is its ability to customize individual learning experience. Furthermore, Huang (2021) examined how Artificial Intelligence Curriculum design is correlated with the cultivation of key competencies in students. This is particularly important since academia should carefully assess its capabilities and make a concerted effort to provide the latest knowledge and skills to empower students to face the challenges of future realities (Ellabi, Khan at Shuh, 2019). In addition to students benefits, AI also significantly impact educators and academic institutions through innovative content creation and fostering a collaborative learning environment.

Additionally, AI assists researchers in analyzing large data volumes, discerning trends and patterns, thus facilitating the development of new theories and addressing intricate challenges in various study areas (Kuleto, et al. 2021).

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Integrating AI into Competency-Based Education in Industrial Technology Program in Nigeria

Integrating AI into Competency-Based Education in Industrial Technology Program in Nigeria involves using AI for personalized learning, adaptive assessments, curriculum development, and skills forecasting while addressing challenges like infrastructure, AI literacy for educators and students and ethical considerations. Key benefits include tailored content, improved engagement, real-time feedback and ability to align skills with industry demands. Implementations require careful planning, investment in AI tools and infrastructure and robust ethical frameworks for responsible use.

Table 1 summarizes selected studies on AI in CBE between 2015 and 2025.

Author(s)	Year	Context	AI Application	Key Findings	Gaps
Wang & Luo	2021	China	AI adaptive learning system	Improved mastery rates	Lack of industry integration
Xu & Brown	2020	US	AI simulations in Industrial Technology	Enhanced problem-solving	High infrastructure cost

Case Study Analysis

- Germany: Dual training system enhanced by AI tools in apprenticeships.
- Singapore: Skills Future uses AI to personalize lifelong learning.
- Nigeria: Recent TVET reforms (NBTE, NSQF) open doors for AI adoption.

Three country case studies were analyzed: Germany's dual training system, Singapore's Skills Future AI initiatives, and Nigeria's evolving TVET framework. Each context demonstrates different levels of AI adoption and CBE integration.

Table 2 provides a comparative summary.

Country	AI Adoption	CBE Integration	Lessons Learned
Germany	Medium	High	Strong industry links
Singapore	High	High	State-driven innovation
Nigeria	Low	Emerging	Need policy reform

Empirical Insights (2015–2025)

1. Adaptive Learning Systems: AI tutors can personalize instruction to each learner (Wang & Luo, 2021).
2. VR and Digital Twins: AI-driven simulations make hands-on skill practice safer and more effective (Xu & Brown, 2020).
3. Predictive Analytics: Learning analytics help identify struggling learners early (Siemens & Long, 2019).
4. TVET and AI Integration: UNESCO (2022) emphasizes AI adoption as central to future-ready vocational systems.

Benefits of AI Integration in CBE

1. **Personalized Learning**
AI can create adaptive learning paths, provide personalized content and tailor assessments to individual students needs and skill levels.
2. **Enhanced Engagement**
Interactive AI-Powered tools, virtual simulations and AI chatbots can offer immersive learning experiences and real time feedback, thereby improve students engagement.
3. **Data Driven Insights**
AI can analyze learning data to identify student challenges early, inform instructional design and provide insights for continuous improvement of the curricular.
4. **Curriculum Design**
AI tools can help analyze industry trends to design adaptive and future ready Competency-Based curricular that meet evolving job market demands.
5. **Skill Forecasting**
AI can help predict future skill needs, ensuring that industry technology programs develop competencies that are relevant and are in demand for the 21st century.
6. **Administrative Efficiency**
AI can automate administrative tasks, freeing up educators to focus on teaching and personalized student support.

Considerations for Implementation of AI in CBE

AI Literacy

Both educators and students need training to understand and effectively utilize AI tools for learning and to develop critical literacy skills for future careers.

Industry Collaboration

Partnerships with industries can help ensure that AI integration aligns with real world workforce needs and provide practical training opportunities.

Infrastructure and Resources

Investment in the necessary AI tools, platforms and infrastructure is crucial for successful implementation.

Ethical Frameworks

Clear ethical guidelines are necessary to ensure responsible and equitable use of AI particularly concerning student data privacy.

Curriculum Integration

AI needs to be thoughtfully integrated into existing learning experiences rather than being an add-on.

Practical Steps for AI Integration in CBE

Access Current State: Evaluate existing CBE frameworks, infrastructure and educator/student digital literacy.

Invest in AI tools – Select and Implement: AI powered learning platforms, simulation tools and assessment software.

Provide Training and Support: Offer comprehensive training programs for staff and trainers to build AI competencies.

Foster Collaboration: Engage in partnerships with industry to identify skill gaps and incorporate relevant AI technologies into the industrial technology program curriculum.

Monitor and Evaluate: Continuously assess the impact of AI integration on students' performance, engagement and learning outcomes and adapt the strategy as needed.

Challenges of AI Integration in CBE for Workforce Development

Some of the challenges to address while integrating AI-CBE for workforce development includes:

1. **Infrastructure and Resources:** Ensuring adequate technological infrastructure and access to AI tools is crucial for effective implementation.
2. **Educator Training:** Training educators to effectively use and integrate AI tools and concepts into their teaching is essential.
3. **Curriculum Integration:** Developing strategies to integrate AI seamlessly into existing competency-based curricular can be complex.

4. Ethical Considerations: Addressing ethical concerns related to data privacy, Algorithms bias and responsible AI use is vital for equitable and trust worthy implementation.

Conclusion

AI-powered CBE offers a new way forward in preparing industrial workers. By personalizing learning, verifying competencies, and aligning outcomes with industry demands, it can revolutionize workforce training. Still, challenges like ethics, infrastructure, and teacher readiness must be addressed.

Recommendations:

1. Governments should adopt AI-CBE in policy and qualification systems.
2. Institutions should invest in AI tutors and digital labs.
3. Industry and academia should co-create training programs.
4. More pilot studies are needed in developing countries.

AI-powered competency-based training represents a paradigm shift in Industrial Technology education. It enables scalable personalization, continuous assessment, and alignment with industrial skill demands. However, ethical concerns, infrastructure limitations, and access inequities remain pressing challenges. Future research should focus on empirical studies, pilot programs, and cross-national comparisons to validate the AI-CBE integration model

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ARTIFICIAL INTELLIGENCE ADOPTION FOR SKILL DEVELOPMENT IN ENHANCING QUALITY TECHNICAL AND VOCATIONAL EDUCATION IN NIGERIA: AN EXPLANATORY REVIEW ANALYSIS

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Abstract

Technical Education (TE) serves as a critical component for fostering economic development by equipping individuals with the necessary skills to thrive in various industries. Meanwhile, the rapid advancement of technology, particularly in the realm of Artificial Intelligence (AI), has created a pressing need for educational systems worldwide to adapt and evolve. As the global economy increasingly relies on AI technologies, technical and vocational education TVET programmes must adopt artificial intelligence and align their curricula with these advancements to equip students with relevant skills but there seems to be scarcity of studies that dwell on integration of AI in TVET and there is the need to assess the adoption of AI for skill development to enhance quality technical and vocational education and the role played by artificial intelligent in repositioning the programme. Therefore, this paper focused on the exploratory review of concepts and literature on the role of Artificial Intelligence in repositioning Technical and Vocational Education (TVET) skills for quality technical education to enhance economic development in Nigeria. To achieve the broad aim, this study identifies skills development in TVET, the importance of AI in TVET to skill development, and the existing challenges and highlights the transformative potential of integrating AI into TVET. There is an urgent need for substantial investment in AI-related infrastructure within TVET tertiary institutions to provide access to AI tools and technologies, and TVET programmes should be updated to include AI-related courses and concepts.

Keywords: *Technical and Vocational Education, Skill acquisition, Economic Development, Artificial Intelligence*

Introduction

Nigeria's burgeoning focus on technological innovation and economic diversification creates a fertile ground for adopting Artificial Intelligence (AI) in Technical and Vocational education curricula. This convergence presents a dual-edged scenario: On one hand, AI offers unprecedented opportunities to cultivate a highly skilled workforce, aligning with the country's economic aspirations (Adeniran, 2023). On the other hand, the integration of AI in Nigerian educational institutions is hindered by significant obstacles, including inadequate infrastructure and insufficient training resources (Okoro & Eze, 2022). To unlock AI's transformative potential and drive Nigeria's economic growth, it is important to adopt and address the challenges being faced and harness the power of AI in the TVET curriculum. Technology advancement has changed the

way things are done in our everyday life, ranging from business operations, schools, the health sector, engineering, agriculture, religion, legal sector, security, and even the way things are done in the household is not left behind. There is this agitation in the minds of people since the advent of artificial intelligence as an aspect of technological advancement that one day, machines might take over the responsibilities of human beings in any sector of the economy. In the recent past, financial houses and some other organizations providing essential services were jam-packed with personnel of different categories performing different functions. Recently, technology has taken over with the most recent much-talked-about artificial intelligence performing the roles of workers with improved services. As observed by the researchers, most things that were flopped in the past through human biases are now being attended to through AI with little or no bias which has continued to reduce system failures occasioned by human complications to be reduced to the barest minimum. Artificial intelligence (AI) is the study of intelligent machines and software that can reason, learn, gather knowledge, communicate, manipulate and perceive objects (Fausta & OnyeKAPa, 2025). It was reported that artificial intelligence is a branch of computer science concerned with making computers behave like humans. Indeed, it is evident that AI is now behaving like humans in many areas like casting news, and is effectively used in other areas of entertainment, fighting crimes, teaching and learning, and writing minutes of meetings, among others. Hence, its adoption and application in TVET curriculum cannot be an exemption for the programme to attain its lofty goals for economic development in the Nigerian context.

Concept of Artificial Intelligence (AI)

Artificial intelligence (AI) is technology that enables computers and machines to simulate human learning, comprehension, problem solving, decision making, creativity and autonomy. Unlike conventional computer programs designed to follow fixed instructions, AI systems are built with the capacity to adapt and improve through data-driven learning algorithms. At its core, AI encompasses several subspecialties, such as natural terminology transforming (NTT), machine learning (ML), robotics, and expert systems. Machine learning, in particular, allows machine to identify design and make forecast from large datasets without explicit programming (Goodfellow, Bengio, & Courville, 2016). This flexibility makes AI highly significant in areas of expertise such as education, healthcare, finance, manufacturing, and technical and vocational education and training (TVET).

In education, AI serves as Innovative focal point tool by individualized instruction accumulated *knowledge*, guidance, and facilitate predictive logic to encourage student success (Luckin et al., 2016). The concept of AI consequently transcends above automation; it indicates a model *progress towards* creative systems that enhancing human *expertise* enhance the final outcome, and promote innovation in the technological age.

Artificial Intelligence Adoption (AIA)

Artificial Intelligence Adoption (AIA) refers to the blended *structured* and application of AI technologies in a professional setting, institutions, or sectors to optimize workflows, improve decision-making, and adoption of new ideas. It involves not only the application of AI systems but also the readiness of colleague, framework, and policies that permit long-lasting use of AI tools (Dwivedi, 2021). *thriving* artificial intelligence adoption involves position skill with organizational purpose, human resource roles, and technological framework. In education and training, AIA require *integrating* intelligent systems such as flexible learning platforms, digital

simulations, automated appraisal tools, and predictive interpretation to facilitate teaching, learning, and skill growth. The adoption process is guided by factors such as digital competency, profitable investment, availability of data, policy framework and cultural readiness (Marques & Batista, 2020). Meanwhile, in Technical and Vocational Education and Training (TVET), AI adoption can support individualize learning, simulate real-world practices, and strengthen competency-based training models relevant to the labour market. However, barriers to (AIA) such as high-performance costs, ethical concerns, lack of technical proficiency, and infrastructural restraint often obstruct its extensive application, particularly in developing contexts like Nigeria (UNESCO, 2021). Thus, effective adoption requires multi-stakeholder collaboration, capacity building, and strategic policy frameworks that foster trust and inclusivity.

Technical and Vocational Education (TVE)

Education is pivotal in every form of development agenda because it is the hub upon which several other programs revolve. The definition of TVE which surrounds the subject of this paper defines TVE “as a comprehensive term referring to those aspects of the educational process involving, in addition to general education, the study of technologies and related sciences, and the acquisition of practical skills, attitudes, understanding and knowledge relating to occupations in various sectors of economic and social life. TVE has the primary objective of providing platform for acquisition of not only employable skills for the world of work or for job creation but also for social life. The unemployed economically active youth population in Nigeria need to be engaged in productive ventures to help make significant contributions to the national economy and overcome their vulnerability to anti-social forces that use them for activities against the security and peace of the country. They need access to quality education to cultivate skills needed for employment, jobs creation as well as decent living. Formal TVE was originally developed in Nigeria as in most African countries in the 1960s, to meet expected skill requirements of industrialization, but has been slow to respond to structural change and sectoral growth in the informal sector. The intention of the government to use the development of modern industrial sector to serve the domestic market and facilitate the absorption of redundant or surplus workers in the urban economy could not be realized as the modern industrial sector could not absorb the migrants due to inability to generate enough employment opportunities.

Technical and vocational education (TVE) plays a pivotal role in equipping young individuals with technical skills and competencies, enhancing their employability. TVE is distinct for its student-centered and industry-oriented features, often involving enterprises in on-site training. Unlike general education, which highlight theoretical knowledge, TVE is competency-based and directed towards develop learners for employability, entrepreneurship, and *persistent* learning (UNESCO, 2016). It integrates theory with practice, ensuring that individuals are not only knowledgeable but also capable of applying skills in real-world situations. According to the Federal Republic of Nigeria (2014), TVE embrace those features of the educational process involved, in addition to general education, the study of technologies and related sciences and the acquiring of practical skills, attitudes, and knowledge relating to occupations in different sectors of economic and social life. This underscores the dual role of TVE: producing skilled manpower for immediate labor market needs and fostering adaptability to evolving technological and industrial demands. In Nigeria, TVE is critical to addressing challenges such as unemployment, skills mismatch, and low productivity. By promoting technical expertise, creativity, and problem-solving, TVE contributes positively to national growth, industrial development, and the outcome of Sustainable Development Goals (Okoye & Okwelle, 2013). Strengthening TVE through modern

curricula, industry partnership, and digital innovations is vital for building a skilled and *innovative* workforce.

Skill Development in TVET

Basis for Skills Development in Nigeria Investing in knowledge and skills is seen by many governments as the cornerstone of developing an employable and globally competitive work force (AFDB & OECD, 2008). All young people require skills that prepare them for decent jobs so they can thrive and participate fully in their societies. Skills and knowledge are engines of economic growth and social development of any nation. Quality education and skills not only empower the recipients for access to economically and socially rewarding jobs, but also empower them to create jobs, provide opportunities for re-integration of displaced workers and migrants and provide platform for school drop-outs and graduates to transit from school to work. Developing relevant skills and competencies among the youth, poor and vulnerable members of the society is crucial to reducing poverty and poverty-triggered insecurity in Nigeria. This becomes imperative as skills development in the global community is not just a part of a country's human resources strategies, but more of economic growth, poverty reduction and national security strategies. Amid the constantly changing, knowledge driven global world of work, a coordinated strategy to boost labour demand and supply for the promotion of flexible employment growth and quality of jobs in Nigeria through the platform of education for skills is a national priority. This equally demands a strategic interplay between skills development sector and other sectors of the Nigerian economy to enhance labour demand and supply system, thereby reducing the impacts of unemployment, poverty and its attendant consequences in Nigeria.

Investment in education for skills as well as basic health and social protection will empower people to move out of poverty, equip people to be socially mobile and to avoid exclusion, as well as improve resilience for both individuals and society as a whole (AFDB, OECD, & UNDP, 2017). To ensure inclusive growth among individuals and the society at large, there must be a blend between investment in skills and knowledge along with monetary stimulus measures, updated business practice, infrastructures, efficient markets and investment in innovation which are key components for driving sustained growth and prosperity (World Economic Forum, 2017). It has been observed that skilled and knowledgeable workforce not only improve a country's investment climate, it is also a major determinant of productivity and growth as well as international competitiveness (AFDB & OECD, 2008). Provision of skills oriented TVET programs will bring about the nurturing of many skills outlets in the youth population for employment or job creation. Investing in knowledge and skills in Nigeria will help to develop a more employable and globally competitive workforce to drive key sectors that are life blood of the country's economic development and make the country move up the global competitiveness index ladder. The transformation of African economies into globally competitive economies with abundant opportunities for decent work for the young population which constitute a large portion of the continent's population has been hinged on investment in human capital development through acquisition of relevant skills and knowledge. Nigeria has the largest population in Africa and the largest youth population on the continent. As the largest economy in Africa, properly harnessing the vast human resources for the development of the country portends significant advantage to the country and the continent of Africa at large. The country's long-drawn struggle with diverse sectional violence, insecurity, crimes and other social vices impact negatively on the country's image as a haven for investment. These constraints to development have been linked with

persistent high unemployment among the youth and a major cause of unemployment is lack of adequate skills for employment among job seekers (Dike, 2009). In view of this, it is important to explore skills and training system (TVET) in Nigeria and identify the contextual challenges and opportunities for TVET in developing relevant skills for employment and job creation needed for national development.

Importance of Artificial Intelligence (AI) in TVET to Skill Development

Artificial Intelligence (AI) is expanding and perceived as a life-changing force in Technical and Vocational Education and Training (TVET), especially in strengthening skill development for the 21st-century employees. AI technologies such as smart education network, flexible learning programme, practical and increased reality, and predictive interpretation efficient, and workAPLe learning experiences that align with the positive demands of industry (Luckin *et al.*, 2016). By enabling *personalized* instruction, AI establishes that learners acquire skill at their own speed, inscribe distinction in potentiality size while encourage knowledge of both technical and soft ability.

In professional growth, AI develops simulation-based education that mirrors real-world environments, as a result of reducing training costs and risks while enhancing learners' practical proficiency (UNESCO, 2021). For example, AI-powered virtual workshop and simulators allow students in welding and fabrication, automotive repair, or machining to practice frequently beyond material wastage. Moreover, AI-driven help educators identify skill gaps, monitor learner progress, and design targeted interventions that intensified competency acquisition (Dwivedi *et al.*, 2021). In the Nigerian Technical and Vocational Education and Technology context, AI adoption can play a critical role in addressing difficulty such as insignificant teaching resources, obsolete curricula, and skilfulness inconsistency with labour market needs. By bridging these gaps, AI strengthens workforce readiness, improves job prospects, and provides to national productivity and sustainable growth.

Conclusion and Recommendations

Considering the global trend of technological advancement and the current economic situation in the country, the researchers assert the necessity of enhancing quality technical and vocational education to incorporate AI-related courses for skills development. This enhancement will enable participants to foster creativity and innovation while acquiring skills essential for transforming the nation's economy. Furthermore, universal access to AI technologies would benefit both trainers and trainees by facilitating the integration of AI into TVET programs. In conclusion, the researchers believe that the benefits of incorporating AI into TVET education far exceed the associated challenges. Nevertheless, to ensure that graduates of TVET education programs can compete effectively in the global job market and contribute to Nigeria's economic development, it is imperative to adopt AI and effectively address the challenges related to the integration of AI in teaching and learning. In view of this, institutions should provide adequate infrastructure and access to AI technologies to encourage users to engage with AI, conduct periodic targeted training programs that highlight success stories, and foster a culture of creativity and innovation to address the resistance from TVET educators to adopting AI technologies for teaching and learning, take advantage of training and retraining programs focused on the application of AI technologies in their teaching profession and government should ensure adequate measures are in place to combat data piracy, and cybercrime, and address ethical considerations.

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ENHANCING AGRICULTURAL SCIENCE STUDENTS LEARNING OUTCOMES USING THE MODEL OF THE DIGESTIVE SYSTEM OF A BIRD IN MINNA METROPOLIS OF NIGER STATE

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Abstract

Knowledge is considered to be transferred when students are able to understand what has been taught. However, this has not been fully achieved in teaching the internal organs of birds, as many students learn more effectively when they can visualize the concepts. Dimensions and Scopus data base was used to obtain information of the past research relating to the subject matter, a quantitative assessment was done using bibliometry analyses and PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) for quantitative assessment. This review highlights the importance of using models to teach the bird's internal digestive systems. In the past, both digital and handcrafted models have been employed. Nevertheless, there is a pressing need to develop models that are tailored to local contexts, particularly in Northern Nigeria where students have limited access to digital resources.

Introduction

Education is understood as a deliberate and structured system that fosters the development of knowledge, cognitive skills, values, and social competencies essential for both individual advancement and societal well-being. It encompasses formal, informal, and non-formal modes of learning, promoting lifelong development. Modern educational perspectives argue that education should embrace inclusivity and adaptability in response to rapidly evolving social and technological landscapes. In this light, Ukeje and Ometa (2025) discuss how Nigerian education must adapt to global shifts by empowering learners with digital literacy, collaborative skills, and reflective capacities. They advocate for an education system that is participatory, contextually responsive, and development-oriented, preparing learners not just for exams but for meaningful lifelong contribution.

In lieu of this, Nnadi *et al.* (2020) advocated for pre-use evaluations of instructional materials, such as anatomical models, which was believed will significantly improve students' cognitive outcomes in animal science. It was stated that Context-relevant models promote deeper retention, independent thinking, and hands-on learning. Similarly, Kumalasari and Suhadi (2023) introduced “Avipedia” a multimedia-based encyclopedia covering avian anatomy which was found to increase learners' interest, classroom engagement, and understanding of physiological processes. These advancements reflect a growing shift from passive, theory-based instruction toward experiential, technology-enhanced pedagogy. Blended instructional frameworks, such as the BOPPPS model (Bridge-In, Objectives, Pre-Assessment, Participatory Learning, Post-Assessment, and Summary), have further improved the effectiveness of anatomy instruction when coupled with anatomical models.

In Nigeria, Abraham and Lestari (2021) found that the use of such models significantly enhanced students' understanding and retention in biology classrooms, especially in topics related to

digestion and respiration. Likewise, Umaru *et al.* (2022) reported improvements in inclusive and student-centered learning outcomes in Northern Nigerian schools through model-based instruction. These tools allowed learners to relate theoretical content to real-life agricultural practices, fostering a more applied and meaningful understanding. Many of the models used in the past are digital and applicable where there is advancement in technology compare to many areas in Nigeria. The models used by Nigerians are craft model which cannot address the visual needs which models aimed to solve.

Methodology

In systematic review, literatures play a role of facilitators by attempting to answer some salient questions and identify the research gap and areas where further researches are required or propose a new method Khan *et al.*, (2020). In this review, an attempt is made to evaluate the number of literatures available on enhancing agricultural science students learning outcomes using the model of the digestive system of a bird. In other achieve the aim of this review, a literature review was done from the year 2021 to 2025 to retrieve information useful for further studies. PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) (Chen & Zheng, 2019) was used to evaluate the qualitative review while bibliometric analysis was use for quantitative review, there are four stages of PRISMA, they are; identifications, screening, eligibility and inclusion as listed in the figure 1. The information obtained will be our basis for qualitative review where inference was made.

Literature Search

Literatures published were extracted from the Dimensions and Scopus database on the key areas of the topic (this include all published materials in all journals in Dimensions and Scopus database) and screened until the volume was reduced for easy references. As at 21/9/2025, the keywords “enhancing agricultural science students learning outcomes using the model of the digestive system of a bird” were searched on the Dimensions database, 39, 688 documents were found on the database and 318 were on Education. In other to make the study current, the search criteria were limited to the last 5years and 16,683 documents were in the Dimension database relating to the search criteria between the year 2021 and 2025. The filter was first trimmed to Education as the aim of study is on Education; a further trimming to only articles (eliminating Chapter, Edited book, Monograph, Proceedings and Reprint) was done. When the articles were trimmed to Education, 159 documents were in the Dimensions database.

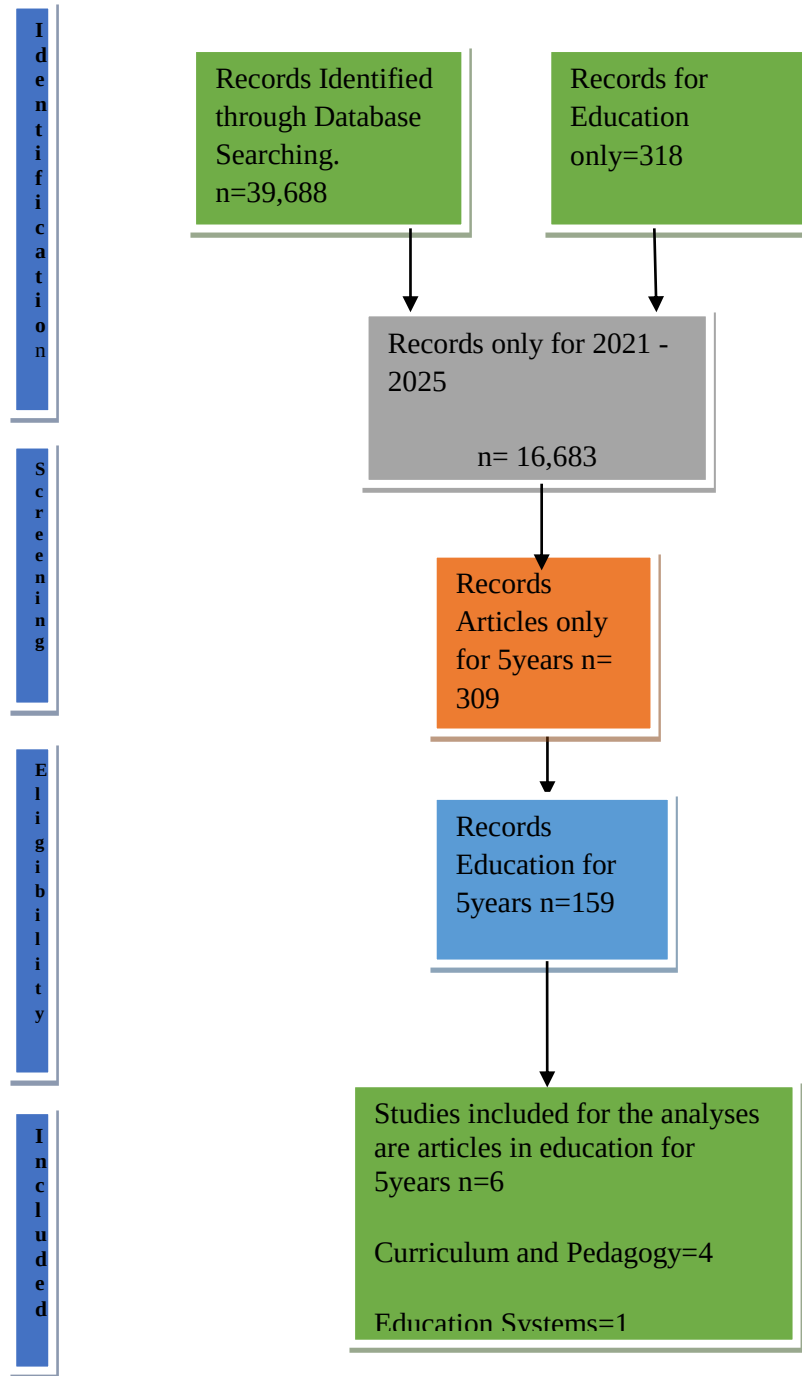


Figure 1: PRISMA 2009 flow Diagram

Identification

Typing all the above search criteria at once into dimensions database brought out 39,688 documents in the Dimensions database, where 318 documents were for educations alone. Since the review was to access the enhance students' comprehension using models a screening was done limit the outcome current and of empirical results.

Screening

A thorough screening was done on the retrieved documents to enhance the quality of this literature review with the aid of Dimensions database. The years were screened to 2021-2025 (that is the last five years). A further limit was done to remove chapters, edited works, monograph, proceedings and preprint.. This led to reduction of the documents to 16,683 documents where 159 documents were on Education.

Eligibility

After limit the documents to empirical data from articles, 309 articles were retrieved from Dimensions database where only six (6) were on something directly related to education.

Inclusion

The six (6) articles were studied and analyzed for discussion. It was observed that the articles cover three major aspect of Education. They are; Curriculum and Pedagogy, Education Systems and Specialist Studies in Education

Table 1: Documents Included for analysis

S/N	Specialization Retrieved	Articles Included
1	Curriculum and Pedagogy	4
2	Education Systems	1
3	Specialist Studies in Education	1

Results and Discussion

As stated earlier there are many publications on the subject matter, although they are not related to Education. The focus of this systematic review is on Education but inference or comparison with the total publication was done.

Year Base

The retrieved documents were breakdown into year; this is to enable easy identification of the number of published articles per year. This article has shown that 2021 has the highest published documents of 6,386 documents. This is followed by year 2022 with 4,431 documents and 2008 with 4,103 documents (figure 2). Education had 17 publications in the year 2021, and 22 publications in the year 2022. It is interesting to know that year 2023 has 74 publications in Education. Table 2 contains the summary of publications and articles published in the last five years. These contain documents in book chapter, edited book, monograph articles, proceedings and preprint.

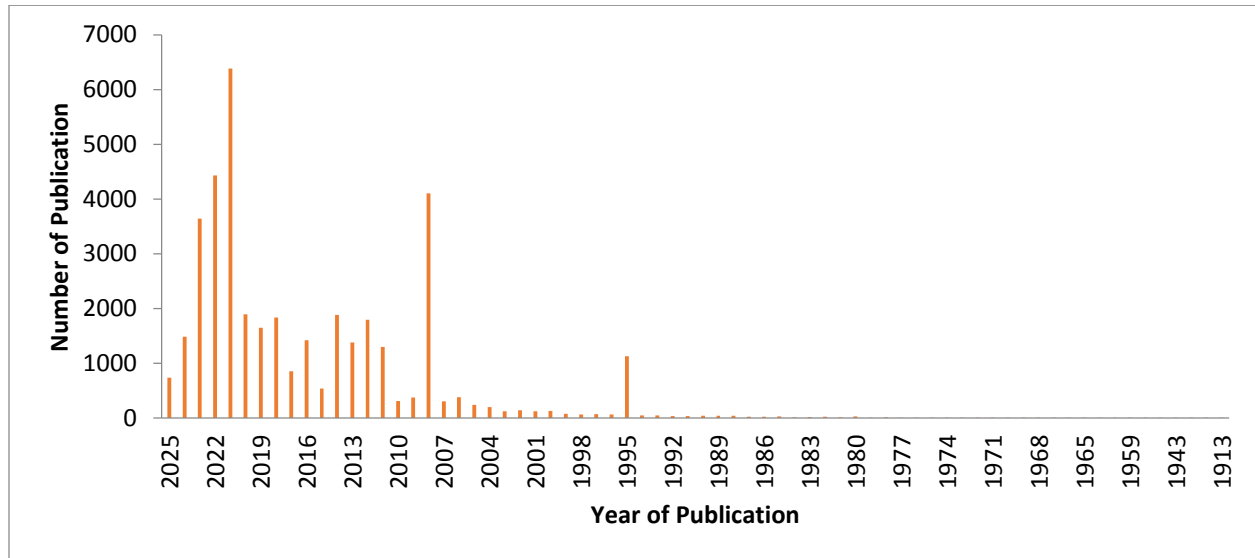


Figure 2: Number of Publication per year

Table 2: Documents and Articles published on the subject matter within the last five years

S/N	Years	Documents Published	Articles Published
1	2025	736	55
2	2024	1487	101
3	2023	3643	57
4	2022	4431	68
5	2021	6386	28

Subject Base

The search criteria brought out several areas of specialization that have published something on the subject matter. This is led by Biomedical and clinical sciences with 655 documents between 2021 and 2025, followed by biological sciences that have published 640 documents. Information and computing, Agricultural, Veterinary and Food and Environmental Sciences have published 623, 617 and 585 documents respectively occupying third, fourth and fifth position (Figure 3). In addition, limiting the criteria to only articles, Biomedical and clinical sciences has 108 documents, Biological sciences 58 documents, Agricultural, Veterinary and Food 51 documents, Psychology 38 documents and Health Sciences 28 documents (Figure 4).

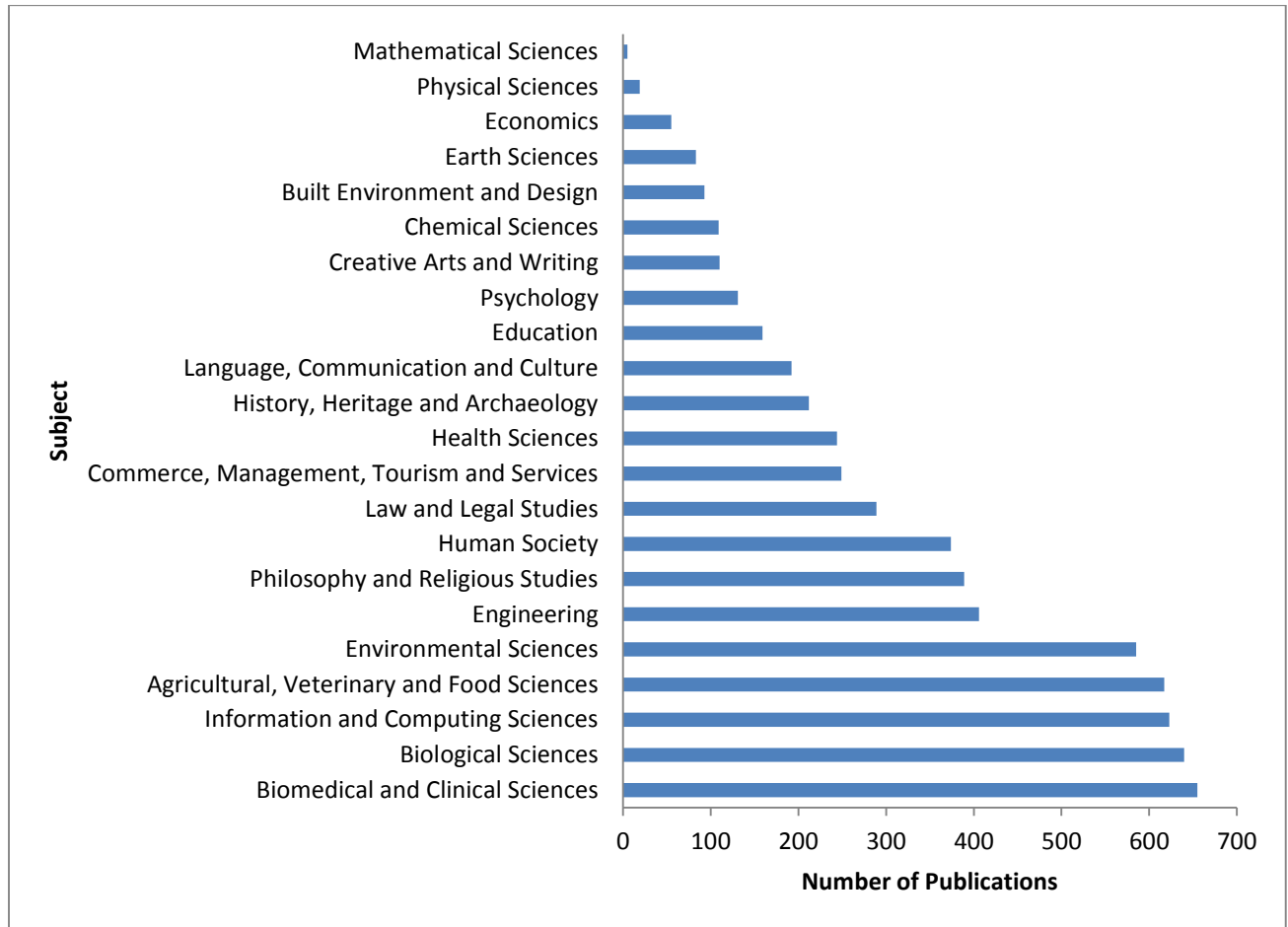


Figure 3: Publication Based on Subject between years 2021 to 2025

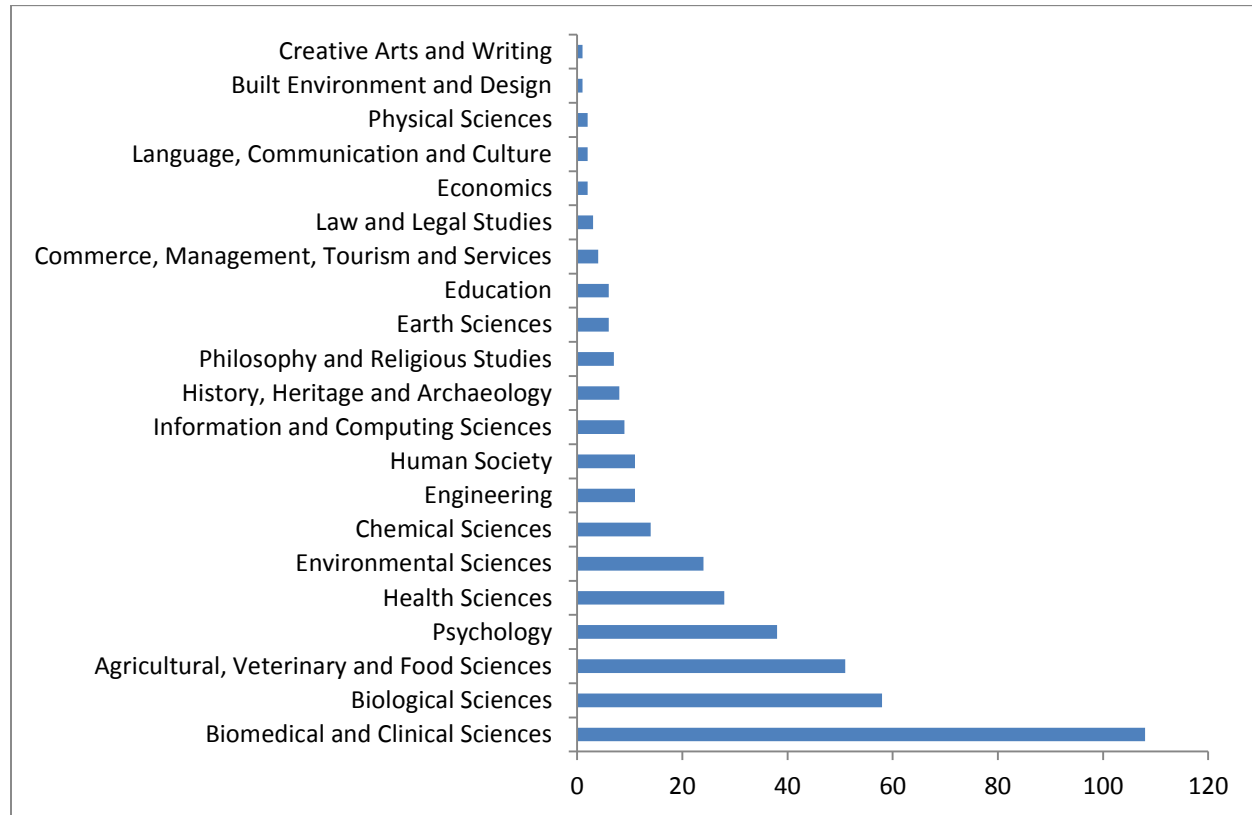


Figure 4: Articles Based on Subject between years 2021 to 2025

Education

Education has a total of 159 documents published in the last five years on the topic reviewed and only 6 articles published within the last five years on the subject matter indicating a wide margin in the knowledge and emphasizing the need to start adopting models in the teaching of bird digestive systems. Figure 5 showed that publication on Education systems was 77, Curriculum and Pedagogy 75 documents, specialized studies in Education 32 documents and Education Policy, sociology and Philosophy 25 documents. In the same vein, 4 articles was published on Curriculum and Pedagogy, specialized studies in Education one article and Education Systems one article (Figure 6)

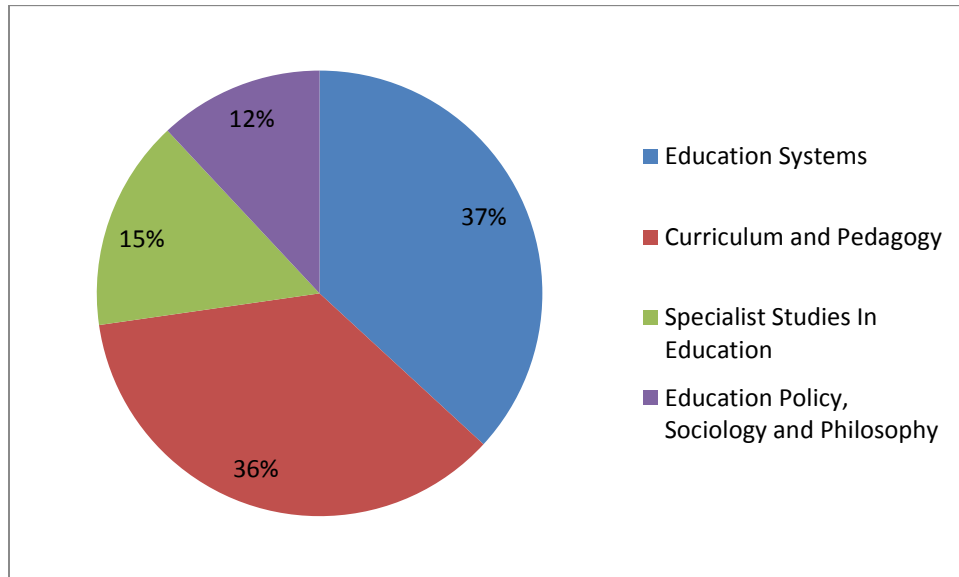


Figure 5: Published Documents on Education within the last five years

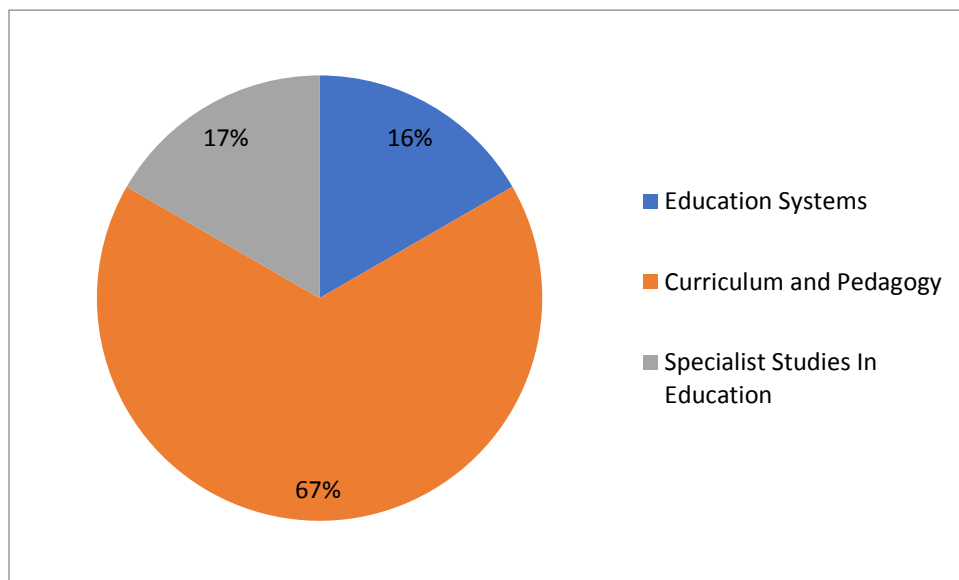


Figure 6: Published Articles on Education within the last five years

Findings on the Articles Related to Subject Matter within the Last five years

Patrícia *et al.* (2024) studied and designed, implemented, and evaluated an educational activity planned for third graders (8 to 13 years old) to explore the intraspecific diversity of vegetables and promote healthy eating habits. The focus was on vegetable. Also, Dempster (2023) evaluated the selection of content in the official biology syllabus for the seventh and eighth years of schooling in four diverse jurisdictions: Kenya, South Africa, British Columbia (Canada) and Singapore. The purpose was to determine whether and how content selection enabled progression to inclusive

generalizations in biology and to compare selection, sequencing and progression among the four jurisdictions. Al-Baz (2024) the extent to which sustainable development goal 2030 by United Nation is introduced to Egyptian curricula for goal is implemented in Sustain primary school student. In addition, the Texas Essential Knowledge & Skills (TEKS) biology standards and three commonly adopted biology textbooks were critically examined to determine the degree of relevancy and inclusion of multicultural content using James A. Banks' Levels of Integration of Multicultural Content (Vasquez and Atwood, 2024). The images that are inserted in the school textbooks of Social Sciences (3rd cycle of Primary Education) was analysed by (Seguido and Olcina, 2023) to assess natural hazards, the type of risk, the degree of catastrophism, and the territorial context to which they are assigned to explain these phenomena in Spain. Although the five previously discussed review discussed introducing new concept into students curricular it was only Kumalasari and Suhadi (2023) that have something on the use models in teaching agricultural and biology students through the use of electronic encyclopedia about bird diversity called avipaedia. Although, this concept is good but it is usage is suitable in places where there is sophisticated equipment. In Nigeria, Umaru et al. (2022) examined the implementation of low-cost, hand-crafted anatomical models in agricultural science classrooms in Northern Nigeria. Their study showed that these models significantly improved student engagement, inclusiveness, and knowledge retention, particularly in underserved schools with limited access to scientific laboratories. Students reported that being able to physically manipulate and explore anatomical structures helped demystify complex internal systems. Hence the need to developed a local model not handcrafted but suitable for students not having access to sophisticated equipment.

Conclusion

This review has shown critical gap in the teaching of agricultural science in Nigeria and the needs to encourage the use of models in the teaching of complex topics of agriculture and biology such as Avian Digestive systems. It also shows the importance of locally generated models for the teaching of Avian Digestive system in Nigeria.

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LEVERAGING WORDPRESS-BASED INSTRUCTIONAL PLATFORMS FOR ENHANCED SOCIAL STUDIES LEARNING: OPPORTUNITIES AND CHALLENGES

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Abstract

This opinion paper examines the potential of WordPress-based instructional platforms to enhance Social Studies learning in upper basic schools, with a particular focus on Minna, Niger State. Social Studies education plays a critical role in developing informed and responsible citizens, yet conventional teaching methods often fail to fully engage learners. Integrating digital platforms like WordPress offers interactive, collaborative and flexible learning experiences that stimulate curiosity, motivation and critical thinking. The paper reviews recent studies on ICT integration, digital competence and WordPress application, highlighting both opportunities and challenges. Opportunities include increased student engagement, access to diverse learning resources, facilitation of collaborative projects and personalised content delivery. However, challenges such as inadequate infrastructure, limited digital literacy, platform maintenance and alignment with curriculum objectives can hinder effectiveness. Based on these findings, the paper recommends strategic lesson planning using WordPress, continuous teacher training, improved ICT infrastructure and supportive policies and funding to ensure sustainable implementation. While existing literature suggests significant benefits, further empirical research is required to validate the effectiveness of WordPress in Social Studies learning across diverse educational contexts. The paper contributes to understanding how technology-enhanced platforms can transform Social Studies education, fostering improved learning outcomes, digital competence and 21st-century skills among students.

Keywords: *Digital Learning Platforms, E-Learning, Educational Technology, ICT Integration, Social Studies Education, Student Engagement, Teacher Digital Competence, Upper Basic Schools, WordPress*

Introduction

Social Studies education a multidisciplinary subject that explores society, culture, history and citizenship, aiming to develop learners' critical thinking, civic responsibility and informed decision-making skills in real-world contexts. Social Studies education plays a pivotal role in shaping informed and responsible citizens, yet conventional teaching methods often fail to fully engage learners. Integrating digital platforms, such as WordPress, can provide interactive and accessible learning experiences that stimulate curiosity and collaboration. According to Russell III and Waters (2021), elementary Social Studies lays the foundation for critical thinking and civic understanding. Iqbal and Kazmi (2023) emphasise that the use of modern technology enhances knowledge retention and learner engagement. Furthermore, Miguel-Revilla, Martínez-Ferreira and Sánchez-Agustí (2020) highlight the importance of digital competence among educators to effectively harness technological tools in teaching Social Studies. Building on the need for digital competence in Social Studies, effective integration of Information and Communication

Technology (ICT) in Nigerian basic education provides the structural and practical foundation for enhancing teaching and learning outcomes.

Information and Communication Technology (ICT) in Education is the use of digital tools, platforms and resources to enhance teaching, learning, communication and administrative processes within educational settings, promoting accessibility, interactivity and efficiency. The integration of Information and Communication Technology (ICT) in Nigerian basic education has gained momentum, aiming to modernise teaching and improve learning outcomes. Adenubi, Samuel and Oyenuga (2025) emphasise the need for structured frameworks, such as DIFTIE, to guide effective digital adoption in schools. Despite these efforts, Social Studies teaching faces persistent challenges, including low student engagement, insufficient instructional resources and reliance on conventional methods (Phinla *et al.*, 2024). The COVID-19 pandemic further exposed gaps in e-learning readiness and digital access, highlighting the difficulties students and teachers encounter in adapting to technology-driven instruction (Aboagye *et al.*, 2021). Given these challenges and the need for adaptable, user-friendly digital solutions, platforms like WordPress offer a promising avenue to support interactive, accessible and technologically enhanced Social Studies instruction.

WordPress-Based Instructional Platform is a web-based content management system enabling educators to create, manage and deliver interactive learning materials, facilitate collaboration and personalise instruction for diverse student needs. WordPress has emerged as a highly flexible and accessible platform for instructional purposes, offering educators the ability to create interactive and customisable learning environments. Its versatility allows for seamless integration of multimedia content, collaborative tools and student projects, supporting diverse teaching approaches (Baran *et al.*, 2021). Ivanov and Tzankova (2020) highlight its effectiveness in delivering online distance education, particularly during the COVID-19 pandemic, demonstrating adaptability to changing learning contexts. Furthermore, WordPress provides affordances such as user-friendly content management, scalability and ease of access, which facilitate both teaching and learning processes (Wu *et al.*, 2020).

Opportunities of WordPress-Based Instructional Platforms

Enhances student engagement, motivation and interactivity

WordPress-based instructional platforms have been shown to significantly enhance student engagement and motivation by offering interactive features that stimulate active learning. Suastika and Sesanti (2025) demonstrated that problem-based learning integrated through WordPress improved fifth-grade students' involvement and understanding in mathematics. Fitriyah and Rindaningsih (2023) also noted increased student activeness and enthusiasm when learning was facilitated via WordPress, as learners could interact with content at their own pace. The platform's multimedia and interactive elements, including quizzes, videos and gamified tasks, foster a more engaging and participatory learning environment, supporting cognitive development and sustained interest in Social Studies and other subjects.

Facilitates access to a variety of learning materials

WordPress enables teachers to centralise diverse educational resources, making them readily accessible to students anytime and anywhere. Alfat and Winarso (2025) found that students exposed to WordPress-hosted learning materials showed improved problem-solving skills, as the platform provided structured access to tutorials, exercises and reference content. Similarly,

Suastika and Sesanti (2025) highlighted the convenience of consolidating multimedia, texts and external links, which promotes independent learning and allows students to revisit lessons as needed. By providing a repository of learning resources, WordPress reduces reliance on physical textbooks and classroom-only instruction, fostering self-directed learning and enhancing students' exposure to a broad range of content relevant to Social Studies education.

Supports collaborative learning, discussions and project-based activities

WordPress platforms support collaborative learning by integrating discussion forums, comment sections and social media links that encourage student interaction. Bogoslov and Georgescu (2020) proposed linking WordPress with social platforms to facilitate peer-to-peer learning and shared problem-solving. Project-based activities are easily managed through WordPress, allowing students to submit work, receive feedback and collaborate online. Karen (2025) emphasised that tools such as chatbots can guide group projects, provide immediate responses and support student collaboration asynchronously. These features create a dynamic learning community, fostering communication, teamwork and collective knowledge construction, which are essential for developing critical thinking and practical skills in Social Studies education.

Allows teachers to personalise content and teaching strategies

WordPress provides educators with flexibility to tailor instructional content and adapt teaching strategies to meet diverse student needs. Alfat and Winarso (2025) observed that teachers could customise problem-solving exercises according to students' proficiency levels, promoting differentiated instruction. Suastika and Sesanti (2025) also highlighted the ease of embedding interactive elements, videos and quizzes aligned with lesson objectives, which enables educators to address various learning styles. Fitriyah and Rindaningsih (2023) noted that personalisation increased student interest and participation. By allowing modifications in content delivery, assessment methods and feedback, WordPress empowers teachers to implement learner-centred approaches that improve comprehension, motivation and academic outcomes in Social Studies and other subjects.

Challenges and Considerations of WordPress-Based Instructional Platforms

Infrastructure issues: internet connectivity, devices, electricity

One of the primary challenges of implementing WordPress-based instructional platforms is inadequate infrastructure, including unstable internet connectivity, limited access to devices and unreliable electricity supply. Alfat and Winarso (2025) observed that interruptions in internet access hindered the smooth delivery of interactive lessons, affecting students' learning continuity. Similarly, Suastika and Sesanti (2025) noted that hardware limitations, such as insufficient computers or tablets, restricted learners' ability to engage fully with online resources. Abah and Chinaka (2024) emphasised that infrastructural inadequacies in schools, particularly in developing regions, can compromise the effectiveness of web-based platforms, making it essential to prioritise resource provision and technical support.

Digital literacy of teachers and students

Effective use of WordPress platforms depends on the digital literacy of both educators and learners. Fitriyah and Rindaningsih (2023) highlighted that students unfamiliar with online interfaces struggled to navigate content, affecting engagement and learning outcomes. Similarly, Alfat and Winarso (2025) emphasised that teachers lacking proficiency in managing web-based

tools were unable to exploit WordPress features fully, limiting interactive opportunities. Bogoslov and Georgescu (2020) suggested that without adequate training, both instructors and students may underutilise collaborative and multimedia capabilities. Therefore, comprehensive professional development and digital skills training are crucial to ensure that all participants can effectively interact with WordPress-based instructional environments.

Platform maintenance, updates and long-term sustainability

Sustaining a WordPress-based instructional platform requires consistent maintenance, regular updates and attention to long-term functionality. Abah and Chinaka (2024) highlighted that web-based platforms can encounter technical glitches, software incompatibilities and security vulnerabilities if updates are neglected. Similarly, Suastika and Sesanti (2025) noted that inactive maintenance often reduces platform reliability, leading to diminished student trust and engagement. Fitriyah and Rindaningsih (2023) emphasised the need for a dedicated support system to monitor, update and troubleshoot the platform. Ensuring long-term sustainability also involves securing funding, technical expertise and institutional commitment to maintain operational effectiveness over time.

Ensuring alignment with Social Studies curriculum and learning objectives

Aligning WordPress-based instructional content with the Social Studies curriculum and intended learning objectives is critical for educational relevance. Alfat and Winarso (2025) noted that poorly structured or misaligned content can confuse students and fail to meet learning outcomes. Suastika and Sesanti (2025) highlighted that while WordPress offers flexibility, educators must carefully design activities to correspond with curriculum standards and lesson goals. Abah and Chinaka (2024) emphasised that integrating assessment tools, multimedia resources and interactive exercises within the platform supports curriculum coherence. Proper alignment ensures that technology enhances pedagogical goals rather than functioning merely as a supplementary or decorative tool in Social Studies education.

Table 1: Summary of Studies on Technology Integration in Education

Author(s) and Year	Location/Area of Study	Research Methodology/Sample	Key Findings
Adenubi <i>et al.</i> (2025)	Nigeria (Basic Education)	(Basic Conceptual framework development	Proposed the Digital Framework for Technology Integration in Education (DiFTIE) to guide ICT adoption in Nigerian basic schools.
Alfat and Winarso (2025)	Indonesia	Experimental study with pre- and post-tests	Found that using WordPress CMS significantly improved students' mathematical problem-solving abilities.

Author(s) and Year	Location/Area of Study	Research Methodology/Sample	Key Findings
Suastika and Sesanti, (2025)	Indonesia	Experimental study with fifth-grade students	Demonstrated that WordPress-based problem-based learning media effectively enhanced student engagement and learning outcomes in mathematics.
Karen (2025)	Russia	Methodological study	Proposed a methodology for implementing chatbots on WordPress to enhance educational services, focusing on interactive learning.
Grant et al. (2025)	USA	Conceptual framework development	Developed a comprehensive approach to teaching elementary social studies, emphasizing inquiry-based learning and critical thinking.
Iqbal and Kazmi (2023)	Pakistan	Survey study	Found a positive correlation between the use of modern technology and increased student motivation and engagement in social studies.
Fitriyah and Rindaningsih (2023)	Indonesia	Experimental study with elementary students	Reported that integrating WordPress in mathematics instruction increased student interest and activity levels.
Phinla et al. (2024)	Thailand	Qualitative study	Identified challenges and innovations in developing a social studies curriculum for 21st-century learners in small schools.
Aboagye et al. (2021)	Ghana	Quantitative study with 141 students	Highlighted challenges faced by tertiary students in e-learning during the COVID-19 pandemic, including technological barriers and lack of preparedness.

Author(s) and Year	Location/Area of Study	Research Methodology/Sample	Key Findings
Baran et al. (2021)	Poland	Case study	Showed that using WordPress for student projects in electronic economy courses enhanced practical skills and understanding of web technologies.
Bogoslov and Georgescu (2020)	Ukraine	Conceptual study	Proposed an architecture linking Facebook and WordPress to support social learning, enhancing collaborative educational experiences.
Miguel-Revilla et al. (2020)	Spain	Quantitative study using TPACK-21 model	Assessed digital competence of social studies educators, highlighting areas for improvement in integrating technology effectively.
Ivanov and Tzankova (2020)	Bulgaria	Experimental study with sports students	Found that WordPress-based online distance education improved learning outcomes and engagement during the COVID-19 pandemic.
Wu et al. (2020)	USA	Conceptual analysis	Conducted an affordance analysis of WordPress, identifying its strengths and limitations as an educational platform.
Russell III and Waters (2021)	USA	Conceptual framework development	Provided a foundational approach to elementary social studies education, focusing on inquiry and civic engagement.
Sund and Gericke (2020)	Sweden	Comparative study	Examined contributions of various secondary school subject areas to education for sustainable development, including social science.

This table provides a concise overview of each study's focus and findings, offering insights into the evolving landscape of educational technology and its impact on teaching and learning.

Conclusion

WordPress-based instructional platforms hold considerable potential to enhance Social Studies learning by promoting interactivity, engagement, collaboration and personalised content delivery. They provide educators with flexible tools to integrate multimedia resources, support project-based activities and cater to diverse learning styles, thereby improving student motivation and understanding. However, challenges such as infrastructure limitations, digital literacy gaps, platform maintenance and curriculum alignment must be addressed to maximise effectiveness. Future research should focus on empirical studies assessing learning outcomes across different contexts and age groups, as well as exploring strategies to sustainably implement WordPress platforms in Social Studies education.

Recommendations

1. **Integrate WordPress Strategically into Lesson Planning:** Teachers should design Social Studies lessons that leverage WordPress' multimedia, interactive and collaborative features to enhance engagement and align with curriculum objectives.
2. **Provide Continuous Teacher Training and Professional Development:** Educators require regular workshops and training sessions to build digital competence, ensuring effective use of WordPress and other e-learning tools.
3. **Strengthen Infrastructure and Resource Provision:** Schools should ensure reliable internet connectivity, access to devices and electricity to support uninterrupted WordPress-based learning.
4. **Develop Supportive Policies and Sustainable Funding Models:** Educational authorities should implement policies and allocate funding to promote the adoption and long-term sustainability of WordPress platforms in Social Studies classrooms.

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ASSESSMENT OF ENVIRONMENTAL AND HUMAN HEALTH IMPACT OF INFORMAL E-WASTE RECYCLING IN SABONGARI LOCAL GOVERNMENT KADUNA, NIGERIA

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Abstract

E-waste describes electrical and electronic equipment or parts of it that have been discarded by the owner without any intention of reuse. The annual global volumes of e-waste are rapidly increasing. In Nigeria, the increasing quantities of e-waste have created avenue where the recovery of inherently valuable fractions from e-waste is performed by a dominating informal recycling sector using crude and primitive recycling procedures which pollute soil, water and the atmosphere with consequent threats to human health and the environment. This study examines level and extent of heavy metal pollution and contamination at the Muchia e-waste processing site in Sabon gari, the ecological risks the metals pose, the carcinogenic and noncarcinogenic health risk of these heavy metals to children under six years. Methods used were experimental elemental analysis of 6 heavy metals (Cadmium Cd, Copper Cu, Chromium Cr, Nickel Ni, Lead Pb, and Zinc Zn). The analysis of the selected heavy metals revealed that the concentrations at the Muchia e-waste processing site exceeded the regulatory limits of the NESREA, Dutch and Canadian Soil Quality and Guidance Values and that contamination extended beyond the main burning and dismantling sites of the informal recyclers to the residential areas. The health risk assessment using the hazard index for both carcinogenic and non-carcinogenic elements indicates that Cr and Pb with a hazard index 1.050 and 1.612 for non-carcinogenic and above the 1 threshold of unacceptable limit pose significant health risks (neurological and developmental disorders) to children under six (6) years. It can be concluded that an appropriate mix of legislation, infrastructure, and local and international collaboration, together with the ability to enforce and ensure the mainstreaming and integration of the informal recyclers could help minimize the environmental and health risks from e-waste processing in Nigeria.

Keywords: e-waste, soil contamination, heavy metals, informal recycling, environmental risk

Introduction

The terms “E-waste”, “electronic waste” and “Waste from Electrical and Electronic Equipment (WEEE)” are used to refer to discarded and nonfunctional electronics. E-waste is different from functional secondhand electrical and electronic equipment, also called “Used Electrical and Electronic Equipment (UEEE)”. E-waste can come from a large variety of products that have plugs or batteries, such as computers, phones, washing machines, air conditioners, lamps, cameras, and more. According to estimates, over 50 million tons of e-waste are generated globally each year, and this amount is projected to reach 120 million tons per year by 2050 (World Economic Forum,

2019). However, in 2019, less than 20% of e-waste is properly recycled, and most of the e-waste is informally recycled in an uncontrolled manner (Forti *et al.*, 2020). Although informal recycling widely exists in many regions of the world, most activities are in low- and middle-income countries. .

High volumes of e-waste have been shipped to Asia and Africa countries, including Nigeria, where e-waste regulations are less restrictive (World Economic Forum, 2019). The proliferation of internet technology, the emergence of "smart cities" in both developed and developing countries, the constant evolution of personal electronic products, and the growing use of solar panels to tackle the climate crisis have all led to a surge in e-waste generation (Jon Hurdle, 2023). The soaring amount of e-waste has raised significant concerns, posing threats to public health and the environment, particularly in developing countries. Informal recycling is often unregulated and fails to meet safety or national environmental standards, posing a threat to worker's health and releasing toxic chemicals into the environment.

Primitive techniques such as dismantling, open burning, metal stripping, acid washing, dumping, etc., are commonly used to extract valuable components from e-waste (Chi *et al.*, 2011). Current studies suggest that workers in the informal sectors usually lack protective equipment, such as gloves or masks, to shield them from exposure (Chi *et al.*, 2011). For example, workers use their bare hands to dismantle large equipment, which often causes cuts and muscle discomfort (Acquah *et al.*, 2021). Another common technique involves heating or burning cables and circuit boards to recover valuable metals like copper and melt unwanted plastic; this process can release toxic chemicals into the atmosphere and irritate workers' eyes and respiratory tracts during their works (Wang *et al.*, 2020). After heating, the remaining part of circuit boards is washed by highly corrosive acids to extract gold, and the acid wastewater, along with other pollutants such as heavy metals, may be dumped into nearby rivers (Wang *et al.*, 2020).

E-waste informal recycling can have a negative impact on human health. However, the associated adverse health effects depend on a variety of factors, and different individuals may have different health outcomes, even living in the same area. The time window of exposure (whether during pregnancy, early childhood, or adult life), e-waste recycling working history, living distance from polluted sites, and co-exposure from other pollutants, can all lead to different health consequences. For example, different types of e-waste recycling jobs can pose different levels of risks. A study found that smelting workers tend to be exposed to higher amounts of hazards than dismantlers and repairers, likely due to poor ventilation in working environments, and more toxicants can be released into the atmosphere by heating (Tahir *et al.*, 2021). Behavioral factors also matter, children who wash their hands more frequently were exposed to lower levels of heavy metals (Xu *et al.*, 2020), and different dietary habits can result in different PCBs exposure from food ingestion (Hashmi *et al.*, 2022).

A larger number of the populace that reside around such primitive recycling factories are at higher risk due to their continual exposure to harmful materials emanating from the recycling activities and processes that are mostly done without any safety measures. This study therefore focused on the assessment of the environmental impacts and possible health risks of potentially toxic metals emanating from e-waste related anthropogenic activities in Muchia, Sabon Gari local Government of Zaria, Kaduna State Nigeria.

Materials And Methods

Study Area

The study area lies within Sabon Gari Local Government Area, Nigeria with a land area of approximately 600 square kilometers. It is bounded in the North by Ikara Local Government, to Makarfi Local Government in the North-West, Giwa Local Government to the West and Zaria Local Government to the South. Sabon-Gari LGA comprises several sub-settlements, namely, Samaru, Hayin-Dogo, Bomo, Dogarawa, Zango, Palladan, Hanwa, Chikaji, Muchia.

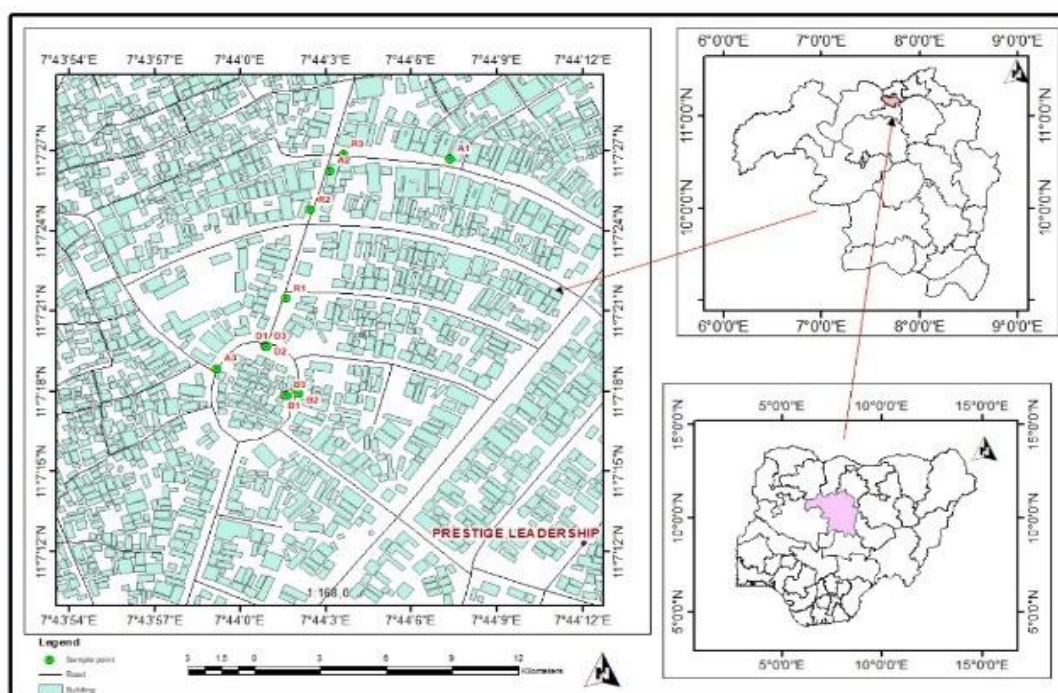


Figure 1.0: Kaduna State showing Study Area

Soil Samples Collection

Soil sampling was done over the entire Muchia e-waste recycling site and its surroundings, i.e. within the areas for dismantling, burning, and residential. A total of 20 samples was collected from the area using a grid and purposive sampling procedure.

Sampling Preparation

The samples were air dried at room temperature, sieved using a 100 μ m mesh, and pulverized into a 2.5 cm diameter thick pellet. Using acid tone, the equipment was cleaned after each procedure to avoid cross contamination.

Digestion of Samples

Each powdered sample was digested according to standard method of digestion. 1g of the sample was weighed into 50 ml beaker, 2.5mls of hydrochloric acid and 7.5 ml of nitric acid aqua regia

solution (1:3) was added. The beaker containing the mixture was put on a hotplate set at a temperature range of 100-170 °C until it was about to dry off or precipitate was observed. Removed and allow to cool, then added some drops of Distilled water. The solution was mixed-up and transferred to funnel set with filter paper. The filtrate was measured and made up to 50 ml. Finally, digests were transferred to the sample bottles for AAS analysis.

Determination of Heavy Metals

Heavy metals in the soil samples were determined according to method reported by Vinogradova *et al.* (2023) using Atomic Absorption Spectrometry (AAS) in which Pb, Cu, Cr, Ni, Zn, and Cd were estimated in the soil samples.

Data Preparation and Exploratory analysis

The heavy metal concentrations values together with the coordinates were prepared and arranged in Microsoft Excel and then loaded into R statistical software for the exploratory analysis. The descriptive variables assessed included the mean, median, minimum, maximum, standard deviation and skewness of the heavy metal concentrations. The heavy metal concentration variables were also analyzed for normality.

Contamination and Ecological Risk Assessment

The assessment of contamination was conducted based on the contamination factor and the degree of contamination. The estimation of the contamination factor in this study was based on

$$C_f^i = \frac{C_{0-1}^i}{C_n^i} \quad (1)$$

and that of the degree of contamination, which is the sum of all contamination factors at a location;

In addition, the ecological risk assessment based on ecological risk factors was conducted and potential ecological risk index determined.

$$C_{deg} = \sum C_f^i \quad (2)$$

$$E_R^i = T_r^i \times C_r^i \quad (3)$$

Health Risk Assessments

The human health risk was assessed as a measure of exposure of a person, and in this case children, to heavy metals. The USEPA (1996) model developed for human health risk was adopted in this study. In this study, the assessment was done based on the three pathways of exposure inhalation, dermal contact and by ingestion

$$Dinh = c(mg/kg) \times \frac{inhR \times EF \times ED}{PEF \times BW \times AT} \quad (4)$$

$$Dderm = c(mg/kg) \times \frac{SA \times ABS \times EF \times ED}{BW \times AT} \times 10^{-6} \quad (5)$$

$$Ding = C \left(\frac{mg}{kg} \right) \times \frac{ingR \times EF \times ED}{BW \times AT} \times 10^{-6} \quad (6)$$

The human health risk due to exposure to heavy metals was estimated, while this was dependent on the hazard quotient determined. The health risk assessment in this study was estimated per the clusters within the Muchia e-waste site.

Results And Discussion

Descriptive Statistics

The skewness values for Cu, Cr and Cd were relatively low (Table 1.0). However, values for Pb, Zn, and Ni were high, which indicates non-normality of the dataset for these heavy metals. The significant differences between the mean and the median of all heavy metals also prove that the datasets were not normally distributed. Furthermore, the coefficients of variation (CV) of Pb and Ni were 1.82 and 6.05 respectively, and higher than those of Cu, Cr, Zn and Cd, suggesting that the former had greater variation among the soils in the study area.

Table 1.0: Summary Statistics for Heavy Metal Concentration (ppm) in Soil

Based on the NESREA, Dutch and the Canadian environmental quality standard for soils, the

Heavy metal s	Mean	Median	Min	Max	Stdv	CV	Skewness	NESREA	Dutch SQGV		Canadian SQGV
									Optimal	Action	
Pb	95321	290.95	14.20	1734.84	1734.84	1.82	3.29	40.00	85	530	140
Cu	46.64	35.25	8.80	153.70	29.17	0.63	1.12	100.00	20	240	-
Cr	296.60	197.30	21.10	1332.00	273.26	0.92	1.57	-	100	380	64
Ni	61.68	13.95	0.60	4003.00	373.36	6.05	10.59	0.05	35	210	40
Zn	1371.14	576.55	41.90	12907.50	1923.75	1.40	3.07	-	40	720	200
Cd	6.56	3.85	0.40	26.50	6.84	1.04	1.35	3.00	1	12	10

mean values of the heavy metal concentrations of Pb and Zn were above the optimal and action values of the NESREA, Dutch and Canadian soil quality and guidance values (SQGV), while those of Cd, Cu, and Ni were below the action-required values. It is also worth indicating that all heavy

metals apart from Cu showed maximum concentrations significantly above the action-required values.

Contamination Factor

Table 1.2 shows summary statistics on the calculation of contamination factor with the detailed location by location contamination factors. According to the Hakanson (1980) classification (Table 1.2) mean contamination factors of Cu, Cr and Ni were 1.86, 2.94 and 0.37, respectively, and thus indicate moderate contamination. The mean contamination factors of Cd, Pb and Zn were approximately 5, 11 and 3 times, respectively, above the lower limit of the high contamination factor. Zn, and Pb showed the highest coefficient of variation in the order 1.15, and 1.62, respectively, while Cd, Ni, Cr, and Cu showed the lowest in the order 1.04, 1.01, 0.90 and 0.61 respectively.

Table 1.2: Summary Statistics of Contamination Factors of Heavy Metals in Soil

Heavy metals	Mean	Median	Stdv	Min	Max	Cv	Skewness
Pb	70.25	23.27	113.64	1.14	472.24	1.62	2.63
Cu	1.86	11.41	1.14	0.35	5.16	0.61	0.99
Cr	2.94	1.98	2.64	0.21	10.99	0.90	1.40
Ni	0.37	0.91	0.37	0.01	1.41	1.01	1.18
Zn	17.85	8.24	20.51	0.60	77.11	1.15	1.60
Cd	32.80	19.25	34.20	2.00	132.50	1.04	1.35

Ecological risk factors

The ecological risk factor for each heavy metal under investigation as well as the overall potential ecological risk were calculated using Equations 2 and 3. The purpose of the assessment is to provide an empirical basis for understanding the ecological risks associated with these heavy metal concentrations in the soils of the Muchia e-waste processing site. The assessment was conducted based on four heavy metals where the toxicity response factor is provided by Hakanson (1980). Table 1.3 lists the summary statistics of the ecological risk factors with detailed potential ecological risk factor for each heavy metal.

Table 1.3: Summary Statistics of Ecological Risk Factors of Heavy Metals

Heavy metals	Mean	Median	Stdv	Min	Max	Cv	Skewness
Pb	351.24	116.38	568.33	5.68	2361.20	1.62	2.63
Cr	5.58	3.95	5.27	0.42	21.98	0.90	1.40
Zn	17.85	8.24	20.51	0.60	77.11	1.15	1.60
Cd	984.02	577.50	1026.51	60.00	3975.00	1.04	1.35

The mean and maximum Cr values show a “low ecological risk”, as the factors are all below 40. This also applies to the mean risk factor for Zn, however, the maximum value indicates moderate ecological risk. The mean and maximum ecological risks for Cd, and Pb are significantly high with

a value above 320. The order of the level of heavy metal toxicity is Cd>Pb>Zn>Cr, indicating that these metals will in this order contribute significantly to the potential ecological risk in the study area.

Health Risk Assessment of Heavy Metals

The highest mean concentration of the heavy metals alternated between the burning and dismantling sites (Table 1.4), which is not surprising as the main activities of e-waste processing take place there. Cd, and Pb showed the highest mean concentrations in the burning sites, while Cu, Cr, Ni and Zn showed the highest values in the dismantling sites.

Table 1.4: Mean Concentration of Heavy Metal per site Cluster

Site	Pb	Cu	Cr	Ni	Zn	Cd
Burning	2666.38	43.81	171.53	21.84	1887.23	10.10
Dismantling	846.84	66.12	419.20	44.64	1939.22	7.81
Residential	896.06	51.53	153.87	44.64	1170.41	2.63

Exposure Pathways of Heavy Metals

Tables 1.5, 1.6 and 1.7 provide the hazard quotients per exposure pathway of Cd, Cu, Cr, Ni, Pb and Zn. The exposure pathways are in the order inhalation Cr> Pb) were the two heavy metals with the highest hazard quotients, and a similar trend was also seen for the dermal pathway. It is also however worth noting that Ni and Zn had the lowest hazard quotient in all three exposure pathways.

Table 1.5: Hazard quotient for dermal exposure pathway for heavy metal.

Hazard quotient (dermal exposure pathway)						
Area	Pb	Cu	Cr	Ni	Zn	Cd
Burning	9.35E-02	5.04E-05	5.26E-02	7.45E-05	5.79E-04	1.86E-02
Dismantling	2.97E-02	7.61E-05	1.29E-01	1.52E-04	5.95E-04	1.44E-02
Residential	3.14E-02	5.93E-05	4.72E-02	7.27E-05	3.59E-04	4.83E-03

Table 1.6: Hazard quotient for inhalation exposure pathway for heavy metal.

Hazard quotient (inhalation exposure pathway)						
Area	Pb	Cu	Cr	Ni	Zn	Cd
Burning	9.33E-04	1.41E-03	1.10E-03	7.43E-07	5.78E-06	1.86E-04
Dismantling	2.96E-04	2.13E-03	2.69E-03	1.52E-06	5.94E-06	1.43E-04
Residential	3.14E-04	1.66E-03	9.88E-04	9.25E-07	3.58E-08	4.82E-05

Table 1.7: Hazard quotient for ingestion exposure pathway for heavy metals

Area	Pb	Cu	Cr	Ni	Zn	Cd
Burning	5.01e+00	1.44E-02	3.76E-01	7.18E-03	4.14E-02	6.64E-02
Dismantling	1.59E+00	2.17E-02	9.19E-01	9.47E-02	4.25E-02	5.13E-02
Residential	1.68E-00	1.69E-02	3.37E-01	8.94E-03	2.57E-02	1.73E-02

Tables 1.5 shows the Hazard quotient for dermal exposure pathway for heavy metals in soil in the study area. The exposure pathways are in the order dermal shows that Cr, Pb were the two heavy metals with the highest hazard quotients.

Tables 1.6 shows the Hazard quotient for inhalation exposure pathway for heavy metals in soil in the study area. The heavy metal Cr showed the highest hazard quotient through inhalation, followed by Pb

Table 1.7 shows the Hazard quotient for ingestion exposure pathway for heavy metals. The exposure pathways in the order of ingestion. (Cr and Pb) were the two heavy metals with the highest hazard quotients, and a similar trend was also seen for the dermal pathway.

Non-carcinogenic Health Risk of Heavy Metals

The non-carcinogenic health hazard indices of Cd, Cu, Ni and Zn for children under 6 years in all study areas within the Muchia e-waste processing site were below the 1 reference limit of environmental and regulatory agencies below which hazards are considered acceptable for children. The value however of Cr in the dismantling site were above the regulatory limit of 1 and considered unacceptable by environmental managers.

The indices for Pb in the areas of burning, dismantling and residential were above the reference limit of 1, and as such considered as unacceptable for children within these areas. In the case of the burning area, the non-carcinogenic hazard index for Pb was five times higher than the reference limit of 1. The high health hazard indices of Cr and Pb in the burning, dismantling and residential areas could be an indication that the activities there could be a contributing factor to the potential hazard posed by heavy metals.

Table 1.8: Non-carcinogenic hazard index for heavy metal in the study area

Area	Pb	Cu	Cr	Ni	Zn	Cd
Burning	5.104	0.016	0.085	0.007	0.042	0.085
Dismantling	1.612	0.024	1.050	0.150	0.043	0.066
Residential	1.715	0.015	0.385	0.009	0.026	0.022

Carcinogenic Health Risk of Heavy Metals

The carcinogenic risk was calculated based only on the risk through inhalation for four carcinogenic heavy metals (Cd, Cu, Cr and Ni) using the model as expressed in

$$LADD = \frac{C \times EF}{AT \times PEF} \times \left[\left(\frac{InhR_{child} \times ED_{child}}{BW_{child}} \right) + \left(\frac{InhR_{adult} \times ED_{adult}}{BW_{adult}} \right) \right] \quad (7)$$

The carcinogenic risk of these heavy metals due to activities within the Muchia e-waste processing site is low, as it is below the threshold range of values 10^{-4} and 10^{-6} . The index of these metals is in the order $Cr > Cu > Cd > Ni$ with risk indices of Cd and Ni alternating depending on the site. The health impact assessment of e-waste recycling activities within the Muchia e-waste processing site showed an overall health risk regarding both carcinogenic and non-carcinogenic effects of the heavy metals identified. With respect to the non-carcinogenic effect on children, the ingestion of particles from the Muchia e-waste processing site appears to be the exposure route with the highest impact followed by dermal contact and inhalation. A similar pattern was also observed by Ferreira-Baptista and De Miguel (2005); Lim *et al.* (2008); Khan *et al.* (2008) and Zheng *et al.* (2010) in their studies of exposure to heavy metals. The hazard quotients of non-carcinogenic risk due to inhalation of fine particles from the Muchia e-waste processing site is 1 to 4 orders of magnitude lower than that of ingestion and dermal contact. This makes the exposure to heavy metals through inhalation less risky to health, as according to Zheng *et al.* (2010) inhalation of re-suspended particles through the mouth and nose is almost negligible compared with ingestion and dermal contact. Furthermore, the above regulatory limits of the non-carcinogenic hazard index of Cr at all sites and that of Pb in the burning, dismantling, residential areas, if contacted by children in high doses, can trigger neurological and developmental disorders (Ferreira-Baptista and De Miguel 2005; Zheng *et al.* 2010). Despite the low health hazard indices of Cd, Cu, Ni and Zn in the Muchia e-waste processing sites, these heavy metals can be cumulative and can affect the kidney (Burbure *et al.* 2003) and other vital human organs, and as such their exposure to children must be avoided.

Table 1.9: Carcinogenic Hazard Risk for Heavy Metals

Area	Cu	Cr	Ni	Cd
Burning	2.2E-08	3.69E-07	9.41E-10	3.26E-09
Dismantling	3.32E-08	9.03E-07	1.92E-09	2.52E-09
Residential	2.59E-08	3.31E-07	1.17E-09	8.48E-10

Conclusions

The environmental impacts of e-waste recycling were evaluated by assessing the concentration and extent of heavy metal contamination in the soils of the Muchia e-waste processing site, and the potential ecological risks the contamination poses to the environment. The following conclusions were drawn:

The results of the analysis reveal that the heavy metal concentrations were ubiquitous within the Muchia e-waste processing site, and that the concentrations in the soils exceeded the minimum and action required limits of the NESREA, Dutch and Canadian Soil Quality and Guidance Values by 10 to 1000 times. Contamination factor, degree of contamination and potential ecological risk indices employed to determine the level and extent of heavy metal pollution in soils at the Muchia e-waste processing site showed that the area is contaminated with six heavy metals, with Cd, Pb and Zn being the major contributors to the contamination in the soil and environment.

The contamination and levels of the heavy metals measured in the soils at the Muchia e-waste processing site pose potential ecological risks to the environment of the Muchia e-waste processing site. The health impacts from the e-waste recycling activities within the Muchia e-waste processing site were assessed by evaluating both the carcinogenic and non-carcinogenic health risks posed by exposure to heavy metal (Cd, Cu, Cr, Ni, Pb and Zn) to local inhabitants, specifically children under 6 years who are more susceptible to heavy metal exposure. The following conclusion can be drawn: In the Muchia e-waste processing site, the exposure pathway that results in the highest level of health risks to children exposed to the investigated heavy metals is ingestion of particles, with Cr and Pb being of most concern in all three exposure pathways.

The hazard indices of Cd, Cu, Ni and Zn were less than 1, thus indicating a relative absence of non-carcinogenic health risks related to the exposure pathways ingestion, dermal contact and inhalation. The hazard indices of Cr and Pb were above the threshold value of 1 for noncarcinogenic hazard risks indicating possible triggers of neurological and developmental disorders in children. The hazard indices for the four carcinogenic heavy metals Cd, Cu, Cr and Ni were below the threshold range of 10^{-4} to 10^{-6} indicating a relative absence of carcinogenic health risks. The index, however, of Cr in all areas is of concern as it is closest to the threshold range. The results of the health risk assessment of the exposure of heavy metals are affected by some degree of uncertainty related primarily to estimates toxicity and exposure parameters. The degree of uncertainty in the health risk assessment does not prohibit the use of the assessment to confirm or reject the existence of unacceptable levels.

Recommendations

Based on the revealed widespread contamination of the Muchia e-waste processing site with heavy metals, the potential ecological and health risks to the environment, humans, and aquatic and terrestrial species, it is recommended that: Further studies need to be conducted on the activities of informal e-waste recyclers, and environmentally sustainable ways proposed to efficiently recover valuable metals from e-waste in Sabon Gari. Given the level and spatial extent of the contamination, the ecological and health risks, urgent precautionary and remediation measures must be taken to prevent the further spread of the heavy metal contamination within the Muchia e-waste processing site. The results of the health risk assessment for the exposure of heavy metals to children within the Muchia e-waste processing site were affected by some degree of uncertainty, which is mainly associated with toxicity estimate values, and only few exposure parameters in Nigeria. This underlines the need for further research into exposure and transport factors at the Muchia e-waste processing site that would help to reduce the currently considerable uncertainty associated with the risk assessment.

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APPLICATION OF DIGITAL TOOLS AND HIGH TECHNOLOGICAL EQUIPMENT FOR IMPROVING TEACHING AND LEARNING OF METALWORK TECHNOLOGY IN TERTIARY INSTITUTIONS IN KADUNA STATE, NIGERIA.

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Abstract

This study investigates the Application of Digital Tools and High Technological Equipment for Improving Teaching and Learning of Metalwork Technology in Tertiary Institutions in Nigeria. Three research questions guided the study, a descriptive survey research design was adopted for the study. The study was conducted in Kaduna state which covers three of the institutions namely Nuhu Bamalli Polytechnic Zaria, Kaduna Polytechnic and Kaduna State college of Education Gidan Waya, each covers one of the senatorial zones. The total of 100 respondents were used for the study, 25 lecturers/Technologists and 75 students. A 26 structured item questionnaire was designed by the researchers and validated by three experts, was used for data collection for the study. The questionnaire was administered randomly to staff and students. Four-point scale was used, Data collected were coded and analyzed on SPSS version 22 and presented in tables. Findings revealed that Digital Tools and High Technological Equipment for Improving Teaching and Learning of Metalwork Technology in Tertiary Institutions are lacking which most manufacturing processes are done manually and Nigeria indigenous business enterprises have failed to fully automate their activities because they lack the technological facilities and trained man power to utilize automated and computerized production systems. The recommendations are Institutions should invest in procuring modern equipment such as Computer Numerical Control machines and welding simulators. Government and private industries should fund digital learning infrastructure in tertiary institutions and technical college.

Keywords: Digital tools & High Technological Equipment, Teaching and Learning, Metalwork Technology.

Introduction

Metalwork trade is among the skilled subject studied in technical colleges, and it is a course offered by all mechanical engineering related trade students in tertiary institution and those studying metalwork technology itself or metallurgical engineering. Metalwork trade programme involve the application of basic scientific knowledge in the design, selection of materials, construction, operation of machines and fabrication of metal products. "It is a mechanical trade offered as general metalwork in Nigeria Technical Colleges", [Federal Republic of Nigeria (FRN 2013)]. Metalwork technology comprises the following areas of specialization which involves (welding, fabrication, machine operation, pattern making, forging etc.) is a core vocational/technical discipline in Nigerian tertiary education (Polytechnics, Colleges of Education Technical and Universities). The researchers view Metalwork technology as a major component of technical education that equips novice or learners with practical and applied skills in welding, machining, fabrication, foundry and forging, iron bending and design construction. Traditionally,

metalwork has been taught using manual tools and conventional machines. However, the rapid emergence of digital tools and high-technological equipment has transformed the way technical skills are taught and practiced globally. Adebayo & Oladipo (2021) says that “The Traditional teaching methods emphasize teacher demonstration and manual practice on conventional machines, on like the Advance in digital tools like (CAD/CAM, simulation software, virtual welding trainers, CNC programming environments) and HTE (CNC mills/routers, laser cutters, automated welding cells, Io T-enabled monitoring, industrial robots). Kalovrektis (2022) states that High digital technological equipment in education refers to advanced digital tools and systems, such as artificial intelligence (AI) Virtual Reality, Augmented Reality, and sophisticated learning management system that process data and enhance the communication Development, and exchange of knowledge to create more immersive, interactive, and engaging learning environments for students. These technologies move beyond basic electronics devices to offer more complex functions to support teaching and learning, and assessment in innovative ways.

These present opportunities to modernize pedagogy, increase safety, shorten learning curves, and better align graduates with industrial expectations for the twenty first century. Digital technology integration in education has grown to be a major worldwide trend that is changing how teachers present material and how students acquire knowledge. Globally, educational systems have adopted online platforms, interactive technologies, and digital resources to enhance instructional efficacy, learning outcomes, and student engagement. This shift is supported by emerging research emphasizing that digital pedagogues, when implemented with institutional support, promote personalized learning, collaborative engagement, and knowledge retention (Bond et al., 2021).

Digital tools such as Computer-Aided Design (CAD), Computer-Aided Manufacturing (CAM), simulation software, and virtual reality (VR), alongside high-technological equipment like Computer Numerical Control (CNC) machines, robotic welding arms, and laser cutters, provide opportunities for precision, safety, and enhanced creativity in teaching and learning of metalwork technology. Digital technologies have become an integral part of everyday life and also of teaching and learning in tertiary institution. Students of today, are often referred to as “digital natives” (Prensky, 2022), have grown up in the digital era, and as such commonly assumed to be expert users of digital technology, with these teaching and learning will easily be shifted toward what the generation are use and often engage with, which will make learning easier and skill acquisition simpler and interesting. Teaching and Learning process should be based on material organized around theoretical principles and experimentation and not on memorizing isolated elements and processes. Wang et al (2020) states that majority of teachers focus on how to succeed longer and deeper learning outcomes from their students by involving them to hands on activities. Education is learning, and a learning technique associated with the Fourth Industrial Revolution and focused on transforming the future of education through advanced technology and automation. The goal is to integrate technology into the curriculum, change the learning process and outcomes, leverage technology and enhance tertiary institution experience. Chicas et al (2020) states that the developments in the field of technology with artificial intelligence, machine learning, chatbots, unimaginable internet speeds, make it imperative that education adapts to these changes, in order to be able to follow the trend and the needs of students in this twenty first century, who are the workers of the future. There is a constant need for jobs in engineering and technology sector, and according to labor market studies, in the future, occupations that do not currently exist will have to be created, to meet the digital age and its demand. According to Psycharis and Kalovrektis

(2022) says that digital technologies and equipment like computer numerical control machines, welding simulators, laser cutters, robotic welding etc are the main pillars to be considered when implementing a tool for effective means of teaching and learning in tertiary institutions.

Application of these high technological equipment is crucial in our institution of higher learning, as it influence students' motivation and learning outcomes, and adaptability to these new digital tools, will developed a high skilled for our graduate and demand for future Employability to meet the industrial skills of the century. If students view these technologies positively, they are more likely to embrace them and develop stronger technical competencies. However, in Nigeria, limited access to digital tools and high technological equipment in tertiary institutions raises concerns about how students perceive their role in improving practical learning of skills to meets the industrial needs of today's manufacturing trends and in the use of artificial intelligence.

Statements of the problem

Globally, industries are demanding technicians who are skilled in digital manufacturing and able to operate high technological equipment. Unfortunately, in Nigeria, most tertiary institutions still relied on outdated machines and equipment, and students have little or no exposure to advanced digital tools in manufacturing sector. This gap has raised questions about graduate from tertiary institution to adapt, to modern industrial practice for the world of works, which is one of the core objectives of technical education programme in Nigeria. Regrettably the performance of metalwork students appears unsatisfactory, as graduate of this programme cannot display their practical skills of metalwork trade with high technological equipment, Ogbuanya and Usoro (2019) noted that at graduation most students are deficient of Employability skills, work place skills, and job generation competencies. Egwu (2017) also asserted that, good technicians are difficult to come by in Nigeria, expatriates working in the country bring in their manpower from abroad due to dearth of competent skill personnel.

As such many of the graduate drop their trade and engage in menial jobs to meet their daily needs and sometimes being engage in unskilled and social vices, constitute them as nuisance in their society, Hence the researchers saw the urgent need to awaken the latent creativity skills in millions of students, with progressive industrialization in the world of works, which this study determine, The Application of Digital Tools and High Technological Equipment for Improving Teaching and Learning of Metalwork Technology in Tertiary Institutions in Nigeria.

Purpose of the study

The purpose of this study is to determine the application of digital tools and high technological equipment for improving teaching and learning of metalwork technology in tertiary institutions in Nigeria. Specifically, the study sought to: -

1. Identify the availability of digital tools and high technological equipment in metalwork workshop in tertiary institution.
2. To what extent if adopted will improve the teaching and learning of metalwork technology in tertiary institution.

Research Questions

Two research questions guided the study -:

1. What is the availability of digital tools and high technological equipment in metalwork workshop in tertiary institution?
2. To what extent if adopted will improve the teaching and learning of metalwork technology in tertiary institution?

Methodology

The study adopted a descriptive survey research design to elicit information's from both Metalwork technology student of tertiary institution and Lecturers of metalwork technology. A total of 100 respondents participated in the study. The population of the study involves 75 Metalwork technology students of tertiary institution and 25 Lecturers/Technologists of metalwork technology. samples were drawn using random sampling technique, sampled from three tertiary institutions in Kaduna state, (Kaduna polytechnic, Nuhu Bamali polytechnic Zaria and Kaduna state college of Education Gidan waya, each from the senatorial zones).

The researchers developed a well-structured questionnaire as an instrument for data collection. Three experts from the department of Industrial and Technology Education Federal University of Technology Minna had a facial content validity for relevance and structure.

The internal consistency of the study was conducted using Cronbach Alpha formula and a reliability co efficient obtained 0.82.

The instrument for data collection was the Application of digital tools and high technological equipment structured questionnaire that addresses the research questions. The researchers distributed the questionnaire with the help of two (2) research assistants to the respondent in their respective institutions.

The researchers used the response code of four point scale, Research question 1 Available and Functional (AF), Available not Functional (ANF), Neutral (N), Not Available (NA), and Research question 2 has strongly Agree (SA), Agree (A), Disagree (DA) and strongly Disagree (SD), in design of the instruments which contained 26 items, of two different sections. The result of the study was analysed using mean statistics. An item with the mean score of 3.00 and above is agreed by student of tertiary institution studying metalwork technology and lecturers in tertiary institutions.

Discussion of the findings

Research Question 1.

What is the availability of digital tools and high technological equipment in metalwork workshop in tertiary institution.

Data presented in Table 1

Mean responses of the respondent on the availability of digital tools and high technological equipment in metalwork workshop in tertiary institution.

S/N	ITEMS	Mean	Remarks
1	Computer Numerical Control (CNC) lathe machines are available.	3.00	Agreed
2	CNC milling machines are available for teaching and learning in my institution.	3.50	Agreed
3	Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) software are accessible for use.	3.50	Agreed
4	3D printing machines are available in the metalwork workshop.	3.00	Agreed
5	Laser cutting machines are available for practical training.	3.00	Agreed
6	Plasma arc cutting machines are accessible in the workshop.	3.40	Agreed
7	Welding simulators are available for student training.	3.00	Agreed
8	Robotic equipment are available for welding and fabrication processes.	3.50	Agreed
9	Digital measuring instruments (e.g., digital calipers, Coordinate Measuring Machine) are available for use.	3.00	Agreed
10	Augmented Reality (AR) tools are available for metalwork training.	3.00	Agreed
11	Virtual Reality (VR) tools are available for metalwork training.	3.50	Agreed
12	My institution regularly upgrades or acquires modern digital equipment for metalwork technology.	3.50	Agreed
13	Digital technological equipment available in my institution meets current industrial needs.	3.00	Agreed

Table 1 shows that 13 items of the availability of digital tools and high technological equipment present in metalwork workshop in tertiary institution had their mean from 3.00 and above were agreed by both Lecturers/Technologist and student offering metalwork Technology in tertiary institution in Kaduna State Nigeria.

Research Question 2.

To what extent if adopted will improve the teaching and learning of metalwork technology in tertiary institution?

Data presented in Table 2

Mean responses of the respondent as To what extent if digital tools and high technological equipment if adopted will improve the teaching and learning of metalwork technology in tertiary institutions.

S/N	ITEMS	Mean	Remarks
1	Adoption of high digital technological equipment will enhance practical skill acquisition in metalwork technology.	3.00	Agreed
2	Digital technologies will improve accuracy and precision in metalwork operations.	3.00	Agreed
3	Using CNC machines, CAD/CAM software, and welding simulators will increase student engagement and interest.	3.50	Agreed
4	Adoption of 3D printing and robotics will improve curriculum delivery in metalwork technology.	3.00	Agreed
5	Exposure to advanced digital tools will better prepare students for industry standards.	3.00	Agreed
6	Augmented reality (AR) will promote problem-solving and creativity among students.	3.00	Agreed
7	Adoption of Visual reality(VR) will promote problem-solving and creativity among students.	3.50	Agreed
8	Digital equipment will speed up training and make learning more efficient.	3.00	Agreed
9	High-tech equipment improves accuracy and efficiency in practical learning.	3.00	Agreed
10	Using simulators and CAD reduces material wastage during skills training for better learning.	3.00	Agreed
11	Exposure to modern tools increases my confidence in handling industrial jobs because of the operational knowledge and skills I acquired.	3.50	Agreed
12	Digital tools when adopted will help student understand theoretical concepts better,with less stress.	3.00	Agreed
13	I believe digital technologies prepare me better for future employment with confidence into the world of works.	3.00	Agreed

Table 2 shows that, the 13 items were agreed, because the mean score is 3.00 and above, as To what extent if digital tools and high technological equipment if adopted will improve the teaching and learning of metalwork technology in tertiary institution.

Discussion of Findings

The findings of this study presented in table 1, revealed that Computer Numerical Control (CNC) lathe machines are available in the metalwork workshop, CNC milling machines are available for teaching and learning in my institution, Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) software are accessible for use, 3D printing machines are available in the metalwork workshop, Welding simulators are available for student training, Digital measuring instruments (e.g., digital calipers, Coordinate Measuring Machine) are available for use, Virtual Reality (VR) or Augmented Reality (AR) tools are available for metalwork training, The availability of digital technological equipment in my institution meets current industrial needs. All these equipment are lacking in our workshops which is in agreements with, Shrestha (2020) states that the future of education system will be enabled by a collection of emerging digital technologies, which will create ubiquitous, immersive, adaptive and personalized learning experience, Remote access lab prototypes are vital for the education of future engineers that will help in modern manufacturing In engineering fields. Whereas most of the digital and high technological machines are absent in our workshops. Which is in consonant with Okwori (2017) which says Inadequate equipment and instructional materials, shortage of facilities and equipment, which create gaps between theory and practice, skills the present system is providing for graduate is theoretical and the emphasis in our country is on certification rather than acquisition of skills that is functional and will make them self reliant, Mike (2011) in Okwori (2017) which states that Nigeria technological growth is behind that of industrialized nations, most manufacturing processes are done manually and most business enterprises have failed to fully automate their activities because of lack of technological facilities and trained man power to utilize automated and computerized production systems. The poor state of Nigeria's technology has led to high cost of production and poor quality output of Nigeria's industrial products.

The findings for research question 2 shows that 13 items were agreed by the respondent which is Adoption of digital tools and high technological equipment will enhance practical skill acquisition in metalwork technology, Using CNC machines, CAD/CAM software, and welding simulators will increase student engagement and interest, Adoption of 3D printing and robotics will improve curriculum delivery in metalwork technology, Digital equipment will speed up training and make learning more efficient which is in consonant with Lund & Aagaard, (2020) states that digital tools could be used to support teaching and learning, which may encourage transformative digital agency and engagement with the new digital technology. Wirani et al., (2022) which says these digital tools are successful in enriching the learning experience and fostering active involvement among students and were helpful increasing knowledge and confidence. The opinion of authors above help to justify the findings of this study.

Conclusion

By definition, all students are “digital natives” in the sense that they have grown up in digital era. However, students today are heterogeneous group as regards to their attitudes toward the use of digital tools and Technology in education. Digital tools and High Technological Equipment have strong potential to enhance teaching and learning of metalwork technology, improving safety, skill acquisition, and alignment with industrial needs. However, adoption in Nigerian tertiary institutions faces practical constraints that must be addressed through coordinated policy, funding, and capacity building, because Students recognize the importance of digital tools and high

technological equipment in improving metalwork practical learning. However, their limited access to these technologies reduces the effectiveness of their training.

Recommendations

1. Institutions should invest in procuring modern equipment such as Computer Numerical Control machines and welding simulators.
2. Government and private industries should fund digital learning infrastructure in tertiary institutions and technical colleges.
3. Teachers Training: regular professional development and certification programs in CAD/CAM, CNC programming, and simulator-based pedagogy, and teachers should receive training on integrating digital tools and high technological equipment into teaching and learning process.
4. Students should be given more opportunities for hands-on practice using advanced tools to meets industrial demands.
5. Policy makers should revisit the curricula to reflect the use of digital tools and modern Industrial technologies.
6. Public–Private Partnerships (PPP): partner with industry for equipment donations, internships, and curriculum co-design.

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HARNESSING ACTIVE AND PEER TUTORING LEARNING STRATEGIES TO IMPROVE ACHIEVEMENT, RETENTION AND ATTITUDES TOWARD MATHEMATICS IN SENIOR SECONDARY SCHOOLS

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Abstract

Mathematics remains a critical subject for intellectual, technological and national development, yet students' persistent underachievement in the subject continues to trouble educators. This opinion paper argues that the integration of active and peer tutoring learning strategies can transform mathematics instruction and learning outcomes at the senior secondary level. Drawing upon current literature (Akudo et al., 2025; Passion & Marcelo, 2024; Dada et al., 2023), it advocates for a shift from teacher-dominated pedagogy to learner-centred and collaborative approaches that promote engagement, critical thinking and sustained retention. It further contends that peer tutoring and active learning not only improve academic performance but also build confidence, motivation and positive attitudes toward mathematics. The paper concludes with implications for teachers, policymakers and researchers, highlighting the need for structured implementation and professional development to sustain the benefits of these innovative strategies.

Keywords: Active learning, Peer tutoring, Mathematics education, Achievement, Retention, Student attitude

Introduction

Mathematics education plays a pivotal role in preparing learners for the challenges of a data-driven, problem-solving society. As Agbata *et al.* (2024) affirm, mathematics underpins technological innovation and everyday decision-making, thereby serving as a foundation for national progress. However, a recurring challenge in many secondary schools especially in developing contexts—is the low achievement and waning interest of students in mathematics. This situation has prompted educators and researchers to rethink instructional approaches. Traditional teacher-centred methods, while efficient for content delivery, often fail to sustain learners' engagement and long-term understanding. Kalita and Nath (2025) observed that didactic teaching emphasises rote memorisation at the expense of conceptual reasoning. This observation underscores the urgent need to adopt more participatory strategies that make students active contributors to their learning processes. Among such strategies, active learning and peer tutoring stand out as promising, evidence-based methods that promote deeper understanding and foster social interaction in learning environments. This paper presents a scholarly opinion on how these strategies when integrated effectively can significantly enhance mathematics achievement, retention and attitudes among senior secondary school students.

Rethinking Mathematics Learning: From Passive to Active Engagement

Active learning represents a paradigm shift from passive listening to active participation. It encourages students to engage cognitively and physically through discussion, problem-solving, reflection and collaboration (Dhivya & Vijeta, 2024). The philosophy behind active learning resonates with constructivist theory, which holds that knowledge is constructed through interaction with one's environment and peers rather than passively received from the teacher.

In mathematics education, active learning may take the form of hands-on problem-solving, think-pair-share exercises, classroom debates on solution strategies and real-world application tasks. These activities stimulate critical thinking and deepen understanding. According to Kalita and Nath (2025), learners exposed to activity-based approaches demonstrate stronger reasoning ability and improved performance compared with those in conventional classrooms.

However, for active learning to thrive, teachers must shift from being information transmitters to learning facilitators. This transformation involves creating spaces where students can explore ideas, make mistakes and learn collaboratively conditions that peer tutoring naturally fosters.

Peer Tutoring: A Powerful Complement to Active Learning

Peer tutoring involves students teaching or supporting one another under structured conditions. It can be same-age, cross-age, or reciprocal, depending on how learners are paired. The approach is grounded in Vygotsky's social constructivism, which emphasises learning through social interaction and the "zone of proximal development." Within this framework, more capable peers guide others toward mastery.

Recent studies strongly affirm the effectiveness of peer tutoring in mathematics education. Akudo *et al.* (2025) demonstrated that cross-age peer tutoring significantly improved students' retention, as tutees benefited from repeated exposure and simplified explanations from peers. Similarly, Passion and Marcelo (2024) reported notable gains in academic performance and self-confidence among students who participated in peer tutoring programmes.

Moreover, peer tutoring transcends academic gains; it fosters interpersonal communication, leadership and empathy. Dada *et al.* (2023) found that underachieving but gifted learners who engaged in peer tutoring experienced improved interest and reduced anxiety in mathematics. These findings indicate that peer tutoring, when integrated with active learning, not only enhances cognitive outcomes but also nurtures affective and social development.

Synergy between Active Learning and Peer Tutoring

While active learning and peer tutoring are effective individually, their integration yields a synergistic effect that maximises learning outcomes. Active learning provides the pedagogical framework for engagement, while peer tutoring personalises and reinforces understanding through collaboration. Together, they create a dynamic learning ecosystem.

In an active mathematics classroom, students can work in peer-tutoring groups to solve real-world problems, justify their reasoning and challenge one another's assumptions. This interactive process develops higher-order thinking skills and reinforces retention. Kishbaugh *et al.* (2018) highlighted that consistent peer-assisted learning fosters not only better retention of content but also resilience and persistence among learners in STEM disciplines.

From a psychological standpoint, the peer relationship in learning reduces intimidation and promotes open communication. Moliner and Alegre (2022) discovered that mathematics teachers who adopt peer tutoring observe improved classroom climate and stronger student engagement. The informal and supportive environment allows students to articulate difficulties without fear of judgement a prerequisite for genuine conceptual understanding.

Implications for Achievement, Retention and Attitude

Enhancing Achievement

Achievement in mathematics depends on students' comprehension, problem-solving ability and sustained practice. Peer tutoring, through repeated explanations and collaborative problem-solving, strengthens these competencies. Akudo *et al.* (2025) reported measurable improvements in test performance following peer tutoring interventions. Similarly, Bello (2019) demonstrated that peer-to-peer strategies outperform mastery learning in improving junior secondary students' academic outcomes in science-related subjects.

Promoting Retention

Retention the ability to recall and apply learned concepts over time improves when learning is meaningful and socially reinforced. Through the tutor-tutee exchange, learners revisit and rehearse concepts, thereby consolidating memory. Kishbaugh *et al.* (2018) and Dada *et al.* (2023) confirmed that peer tutoring enhances long-term retention by reinforcing cognitive links through interaction and repetition.

Fostering Positive Attitudes

Attitude plays a critical role in mathematics learning. Negative perceptions such as “maths anxiety” or feelings of incompetence often lead to avoidance and low achievement. Peer tutoring counters this by creating a friendly learning culture where students learn from equals. Passion and Marcelo (2024) found that peer tutoring reduced anxiety and increased enjoyment of mathematics. The social recognition tutors receive also fosters pride and self-worth, cultivating a positive disposition toward the subject.

Implementation Strategies for Schools

For active and peer tutoring strategies to succeed, schools and teachers must adopt deliberate implementation plans:

1. **Structured Peer-Tutoring Programmes:**
Teachers should design programmes that define tutor–tutee roles, set learning goals and provide supervision. Training student tutors enhances instructional quality and consistency (Machimana, 2020).
2. **Integration into Curriculum Activities:**
Peer tutoring should not be treated as an extracurricular add-on but embedded into mathematics lessons and assessments. Active learning tasks, such as collaborative problem-solving, can be scheduled weekly.
3. **Professional Development for Teachers:**
Teachers need training in facilitating peer-led learning, managing group dynamics and assessing collaborative activities. As Moliner and Alegre (2022) suggest, teacher attitudes toward peer tutoring influence its classroom success.
4. **Evaluation and Feedback Systems:**
Schools should monitor peer-tutoring outcomes using formative assessments, peer reviews and student feedback to ensure effectiveness and sustainability.

Challenges and Considerations

Despite its advantages, implementing peer tutoring and active learning faces challenges that require careful management:

- **Time Constraints:** Preparing and supervising peer-learning sessions can be demanding for teachers already burdened with extensive curricula.
- **Quality Control:** Without proper guidance, misconceptions may spread among learners. Continuous teacher oversight is essential.
- **Cultural Resistance:** In some contexts, hierarchical classroom traditions discourage students from assuming teaching roles. Awareness campaigns and policy support can mitigate this.
- **Equity Issues:** Differences in ability levels may lead to dependency or disengagement if pairing is not carefully structured.

Addressing these challenges requires institutional commitment, administrative support and a gradual shift in teaching culture.

Policy and Research Implications

At the policy level, educational authorities should integrate peer tutoring and active learning into teacher education curricula and national teaching standards. Curriculum planners can design flexible schemes that allow collaborative learning activities without sacrificing syllabus coverage. For researchers, there is a need to explore variations of peer tutoring (e.g., online, reciprocal, cross-age) within blended or digital learning environments. Emerging technologies such as learning analytics can also be leveraged to track peer-interaction patterns and predict learning gains.

Furthermore, longitudinal studies should investigate how sustained peer tutoring influences not only academic outcomes but also social and emotional competencies among students.

Conclusion

Active and peer tutoring learning strategies hold great promise for transforming mathematics education by making learning more engaging, collaborative and meaningful. When students actively participate and learn from one another, they develop deeper understanding, improve their retention and build confidence in their mathematical abilities. These strategies encourage cooperation, communication and problem-solving skills that extend beyond the classroom and prepare learners for the challenges of the modern world. By shifting from teacher-centred instruction to approaches that value student interaction and shared responsibility, educators can create a supportive learning environment that nurtures curiosity, resilience and a genuine interest in mathematics. Ultimately, adopting active and peer tutoring strategies can help shape learners who are not only competent in mathematics but also motivated and confident to apply their knowledge in real-life situations.

Recommendation

Based on the discussions in this opinion paper, the following recommendations are proposed to strengthen the implementation of active and peer tutoring learning strategies in mathematics education:

1. **Teachers should integrate active and peer tutoring methods** into their regular classroom practice to promote student participation, collaboration and deeper understanding of mathematical concepts.
2. **Schools should provide regular training and professional development** for teachers to equip them with the skills needed to plan, facilitate and assess peer-tutoring and active-learning sessions effectively.
3. **Curriculum planners and education authorities should include collaborative learning activities** in mathematics syllabi and assessment frameworks to encourage consistent use of these strategies across schools.
4. **Administrators should create supportive policies and allocate time** within the school timetable for structured peer-tutoring programmes and group-based learning activities.
5. **Students should be sensitised and motivated to take active roles** as both tutors and learners, fostering a classroom culture built on cooperation, respect and shared responsibility.
6. **Researchers should continue to explore innovative models** of peer tutoring and active learning, including the use of digital tools and blended-learning environments, to further enhance mathematics achievement and retention.
7. **Parents and communities should be engaged** in supporting collaborative learning initiatives through encouragement, mentorship and provision of learning resources that reinforce school-based activities.

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HARNESSING PROBLEM-SOLVING STRATEGIES FOR EFFECTIVE GEOMETRY INSTRUCTION: INSIGHTS FROM POLYA'S HEURISTIC AND COLLABORATIVE LEARNING APPROACHES

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Abstract

Persistent underachievement in geometry among secondary school students has become a concern for educators, particularly in Nigeria and other developing contexts. Despite curriculum reforms and increased access to digital tools, geometry instruction remains largely procedural and teacher-centred. This opinion paper advocates for a transformative shift towards problem-solving strategies anchored in Polya's four-step heuristic and collaborative learning approaches. It argues that these methods can significantly enhance students' conceptual understanding, reasoning skills and long-term retention. Drawing on evidence from recent African and global studies, the paper emphasises the synergy between individual reflection and group collaboration in tackling geometric problems. It concludes that systematic incorporation of these approaches in teacher training and classroom practice can revitalise geometry education and cultivate a generation of critical thinkers capable of applying mathematical reasoning to real-world contexts.

Keywords: *Problem-solving, Polya's heuristic, collaborative learning, geometry instruction, mathematics education, Nigeria*

Introduction

Geometry forms a vital component of secondary mathematics curricula worldwide, which develops spatial reasoning, logical thinking and the ability to model physical space skills essential in engineering, architecture and everyday problem-solving. Yet, despite its importance, students in Nigeria and several sub-Saharan African nations continue to perform poorly in geometry. Factors such as over-reliance on rote teaching, limited use of instructional heuristics and inadequate learner engagement contribute to this challenge.

A critical examination of the Nigerian context reveals that many students memorise geometric formulas without understanding their derivations or applications. Teachers often focus on procedural demonstrations rather than guiding students through the reasoning processes that underpin problem-solving. Consequently, learners struggle with applying geometric concepts to unfamiliar problems or real-life situations.

To address these challenges, this paper proposes the adoption of Polya's problem-solving heuristic a systematic approach comprising four stages: understanding the problem, devising a plan, carrying out the plan and looking back. Complementing this is the collaborative learning framework, which encourages peer interaction and cooperative reasoning. Together, these strategies promote deeper comprehension, reflective thinking and shared responsibility for learning outcomes of students.

Conceptualizing Problem-Solving Approaches and Polya's Four-Step Heuristic

The Rationale for Problem-Solving Approaches in Geometry

Problem-solving lies at the heart of mathematics. When learners actively construct meaning through problem exploration, they develop cognitive flexibility and conceptual depth. Research has shown that students' difficulties in geometry often stem from fragmented understanding and lack of heuristic reasoning. Abakah (2023) identified that when students engage in heuristic-driven tasks, they begin to appreciate the structure of geometric proofs and relationships among shapes. Similarly, Chirinda (2016) emphasised that problem-solving provides a platform for reasoning and communication, allowing learners to verbalise their thinking and correct misconceptions.

In Nigeria, where classroom environments are often dominated by teacher explanations, embedding heuristic instruction offers a pathway for fostering autonomy and curiosity. By asking students to interpret problems, formulate strategies *and* evaluate their own solutions, teachers can cultivate metacognitive awareness and problem ownership—essential attributes for mathematical competence.

Polya's Four-Step Heuristic in Action

George Polya's problem-solving model remains a timeless framework for developing mathematical reasoning. The first step **understanding the problem** requires students to identify given information, unknowns *and* relationships. This foundational stage ensures that learners engage meaningfully with the question rather than rushing to computation.

The second step **devising a plan** invites creativity. Students are encouraged to draw diagrams, look for patterns, or relate new problems to previously solved ones. Hassan and Sani (2025) demonstrated that using Polya's method within cooperative learning contexts improved students' persistence and analytical reasoning in geometry.

The third stage **carrying out the plan** focuses on executing strategies while monitoring progress. Teachers serve as facilitators, providing scaffolding rather than direct answers. The final step—**looking back** encourages reflection, verification *and* alternative reasoning, reinforcing long-term retention. This stage also connects geometry learning to other domains such as physics, design *and* engineering.

Incorporating Polya's heuristic in Nigerian classrooms may initially challenge traditional teacher-centred norms. However, evidence suggests that when properly implemented, it enhances students' engagement and confidence. Connolly and Cosgrove (2022) further linked reflective problem-solving to cognitive growth, aligning with Bernard Lonergan's theory of understanding through inquiry a principle resonating with Polya's philosophy.

Integrating Collaborative Learning

While Polya's heuristic supports individual reasoning, collaborative learning complements it by situating problem-solving in social interaction. Students co-construct meaning, negotiate strategies *and* benefit from peer explanations. Fadzil and Osman (2025) conducted a comparative review revealing that collaborative problem-solving enhances reasoning accuracy and promotes equitable participation.

In a similar vein, Ampadu, Narh-Kert *and* Yeboah (2024) found that co-creation between teachers and learners improved pupils' mathematical performance, particularly in complex geometry topics. Collaboration enables learners to externalise their thought processes and confront cognitive dissonance key drivers of conceptual change.

In Nigeria's secondary classrooms, group-based learning can address resource constraints while promoting active participation. When combined with Polya's heuristic, collaboration becomes a dynamic environment where learners question, critique *and* refine each other's reasoning. Such dialogic engagement helps demystify abstract concepts and nurtures a culture of collective inquiry.

Technological and Cognitive Extensions

Recent advances in educational technology provide additional support for heuristic and collaborative learning. Studies like those of Perbowo (2024) and Noverianto *et al.* (2024) illustrate how digital tools such as GeoGebra facilitate visualisation, experimentation *and* hypothesis testing in geometry. These applications allow learners to manipulate shapes dynamically, thus linking abstract reasoning with visual intuition.

Moreover, cognitive research has expanded our understanding of how problem-solving can be aligned with brain-based learning. Kidman and Tan (2025) observed that instructional models grounded in neuroscience principles enhance focus and cognitive engagement, reinforcing the benefits of heuristic and collaborative strategies in STEM disciplines. The integration of these cognitive principles into mathematics pedagogy can strengthen learners' conceptual retention and problem flexibility.

African and Global Perspectives

Across Africa, initiatives aimed at improving mathematics teaching have increasingly emphasised problem-solving competence. In Zimbabwe, Chirinda's model for enhancing mathematical problem-solving demonstrated notable gains in learners' ability to explain reasoning processes. In South Africa, Mahlaba (2021) explored how preservice teachers' discourses revealed evolving geometric reasoning when engaged in reflective problem-solving dialogues.

These findings echo the Nigerian situation, where problem-solving is often undervalued in daily instruction. Adopting heuristic and collaborative strategies can bridge the gap between theoretical understanding and practical application. Internationally, Tractenberg, Lee *and* DeCoste (2024) proposed a Mathematical Problem-Solving Pipeline (MPSP) that provides structured scaffolding for complex tasks, showing how consistent problem-solving frameworks can transform learning in higher education. Applying similar scaffolds in secondary geometry could yield similar improvements.

Implications for Practice and Policy

The integration of Polya's heuristic and collaborative learning in geometry instruction carries multiple implications for teaching practice and educational policy in Nigeria and beyond.

For teachers, the shift requires reorientation from information delivery to facilitation. Educators must guide students through the reasoning process rather than providing ready-made solutions.

Professional development programmes should include workshops on heuristic questioning, reflective dialogue *and* collaborative assessment.

For curriculum developers, embedding problem-solving objectives in geometry syllabi is essential. Assessment should not merely test recall of theorems but evaluate reasoning, creativity *and* adaptability. Formative assessment strategies such as group problem journals and reflective logs can help track learners' conceptual growth.

For teacher education institutions, there is a need to model heuristic and collaborative approaches during preservice training. Exposing future teachers to these methods increases their confidence in adopting learner-centred practices upon graduation.

For policymakers, investment in teaching resources, technological tools *and* professional learning communities can sustain these reforms. The development of problem-solving frameworks aligned with national learning standards will ensure consistency and scalability across schools.

Collectively, these actions can transform the culture of mathematics teaching from procedural performance to reflective inquiry an essential step toward achieving quality education as outlined in Sustainable Development Goal 4.

Conclusion

Problem-solving strategies anchored in Polya's heuristic and enriched through collaboration offer a powerful framework for revitalising geometry instruction in Nigeria's secondary schools. These approaches nurture analytical reasoning, persistence *and* conceptual understanding—skills vital for success in mathematics and beyond. Evidence from African and global studies underscores that when students actively engage in exploring, discussing *and* reflecting on problems, they develop lasting cognitive structures that support higher-order thinking.

By empowering both teachers and learners to approach geometry as a discipline of reasoning rather than memorisation, Nigeria's education system can foster learners who not only solve problems but also understand the processes that underpin solutions.

Recommendations

1. Polya's heuristic should be adopted as a core instructional framework in geometry curricula at secondary levels.
2. Teachers should Promote collaborative learning through structured group tasks, peer tutoring and problem-based projects to encourage communication and critical reasoning.
3. Integrate technology tools such as GeoGebra and virtual manipulatives to visualise geometric concepts and support heuristic exploration.
4. School authorities should provide teacher with training that focuses on heuristic questioning techniques, cooperative assessment *and* reflective pedagogy.
5. Government should encourage school-based research on problem-solving practices to generate local evidence for continuous improvement.

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INFLUENCE OF ARTIFICIAL INTELLIGENCE-DRIVEN ADVERTISEMENT PLATFORMS ON PROCUREMENT, BIDDING EDUCATION IN RADIO NIGER AND NIGERIAN TELEVISION AUTHORITY(NTA) MINNA

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Abstract

Communities wishing to be important members of the 21st century society need to advertise procurement bidding education in the mass media so as to optimize their chances of realizing appropriate services and products in building their societies. This study aims to find out, how artificial intelligence has been used to carry out advertisement on procurement bidding in Radio Niger and Nigerian Television Authority, explore the educational use and importance of artificial intelligence in human resources management as well as products. This paper is anchored on Technology Acceptance Model of Fred Davies (1989), Technological Determinism Theory of McLuhan (1964) and Diffusion of Innovation by Everett Roger. Purposive Sampling was used to collect and analyzed data from questionnaire items from May 2024 to April 2025 on both broadcast media. Findings revealed that were not adequately educated on A.I. Driven advertisement on procurement bidding, poor patronage of the procurement bidding advertisement and dominant phobias that A.I. will render the people unemployment. Recommendations were made were made on how to see A.I. procurement bidding education, as efforts of technology improve the Niger people of Nigeria and make the place a better one

Introduction

An integral component of the mass media is the broadcast media. They comprise of the radio, cinema and the television., Radio and the television serve multiple purposes of education, informing, mobilizing, entertaining, integration of values and norms, as well as broadcast messages from senders to receivers of both goods and services using artificial intelligence(A.I) to harness marketing communication of procurement business and customers' engagement (Vankatesan&Lecinski, 2021). The radio and the television are central and most pervasive mass media in developing societies like Nigeria. They play historic, distinctive and unprecedented roles of socially homes as well as advertising messages of goods and services. They make specific and suitable contributions to listeners and viewers conception of reality. Radio Niger and Nigerian Television Authority (NTA) Minna are in Niger state of North Central Nigeria. They ensure that impartation of ideas and making oneself understood by others (Nwa Bugwu, 2023), transfer of information, ideas understanding or feeling among people (Monday and Peramentux) as well as transfer of ideas from sender to the receiver (Akpanabia, 2015) are effectively transmitted. These aid procurement bidding advertisements(ads) on their platforms. Procurement which is a process of locating and agreeing to terms and purchasing goods, services or other works from an external source with the use of a tending of competitive bidding is stimulated to raise to desired responses. Procurement agents advertised procurement demands to attract best possible products and services from bidders through the broadcast media which in turn ensures optimization of cooperate goals and objectives processes to realize optimal (Kotler ,Kartajaya and Setiawan;2019).

But the ability of machines that think, analyses learn and decide in a rational way, what is analogous to how human beings do, have increasingly aided, the society to improve health care, education, facilitate, access to information that can enhance business and mutual profitability for both owners of products and services as well as their clients. The services of artificial intelligence in all human activities have become a *sin qua non* of this digital age in every society (Rust and Huag 2021).

Artificial intelligence (AI) displays the ability of the computer or computer control robots to perform tasks commonly associated with intelligent being has further enhanced procurement bidding activities through the radio and the television (Kotler, Katajaya & Setiawan, 2021) Artificial Intelligent related decisions, enable procurements' teams to make vital choices from huge amount of complex data. They can provide more information in real-time for procurement teams which can be used to facilitate and improve their decision making before advertising their beddings for human resources, products and services in broadcast media platforms(Sinha & Unemyr;2019). This is in consideration of supplier market contract, negotiation risk, management and performance evaluations (Venkatesan and Lecinski2021).

Added to this, Niger state community is among the Nigerian communities that are still evolving. The state (Niger) is experiencing the digital revolution especially in the area of Artificial intelligence (A.I). A.I is an area of computer science that emphasis the creation of intelligent machines that work and react like human beings. Their examples include: Automation, Machine Learning, Machine vision, Natural Language Processing (NLP), Self-driving cars and Robotic (Rouser 2018). Other types include; drowns, artificial assistance, Prostherlilis, Exoskeleton, Medical robots and Advertising Automation tools which is the focus of this paper. It is design to manage and optimize digital advertising campaigns with speed and precision. It can also be called Advertising Robots, Advertising Bots or Advertising Automation tools. They are used to carry out different types of advertising from generate advertising, creative copy to optimize advertising budgets and product advertising campaign performance (Bhardwaj & Noble, 2019).

Artificial intelligence influence on creative media advertisements platforms leverages user browsing history and preferences to get advertisements precisely, the intelligent targeting ensures that the advertising reach the most relevant audience ultimately maximizing their campaigns effectively and conversation rates. A.I-driven ads. help advertisers in the broadcast media to understand the audience based on collective data and allows one to create and target, personalize, dedicated to procurement activities. Be that as it is, how have the broadcast media educated the Minna heterogenous public on the advantages of A.I in this digital age on procurement bedding activities. How knowledgeable are the staff of the broad cast media and how do they influence, A.I – driven Ads on procurement biddings?

Aim and objectivities of study.

The aim of this study is to find out how the two- broadcast media have educated their public on A.I – driven ads on Procurement bidding activities in 2023 and 2024. Specifically this aim can be achieved through the pursuance of the following questions and hypothesis

Research Questions

1. What broadcast frequency do the media have?
give to educate the public on A.I – driven advertisements on procurement biddings?
2. What is the comparative level of patronage on A.I. – driven advertisements between the broadcast media?
3. what challenges affect use of A.I driven education on advertisements of procurement bidding from September 2023 to August 2024 in the broadest media?
4. what is the extent of broadcast media use of A.I.-driven ads for marketing communication of procurement bidding?

Hypothesis

This study tested two null hypotheses.

H.O.1. There is no significant relationship between exposure to A.I- driven education by advertisement of procurement bidders in Radio Niger and NTA Minna.

H.O.2. There is no significant relationship between exposure to A.I- driven education advertisements on the broadcast media and procurement activities in Minna.

Statement of the Problem

Over the years A.I. have grown in its usage for creating awareness and have become an essential tool for advertising procurement bidding in this digital age. The emergence of A.I in procurement bidding activities and capital resources. Products and services have greatly improved the method of advertisement placements in multiple procurement activities. However, despite the usefulness of A.I especially in the broadcast media, a lot of audience are skeptical and seem to be accustomed to the channels of the traditional media platforms. They appear to see A.I driven ads as an attempt to take over their jobs(Smith and Anderson;2019) because of poor education on A.I driven activities. One could not help but ask whether the broadcast media have educated the audience enough on the benefits of A.I driven ads in this digital age in influencing the consumer purchase decision on procurement bidding activities. This study seeks to investigate the broadcast media on the influence they have made through the education they have given the audience on A.I driven activities on procurement biddings,

Theoretical Framework

This study is anchored on two theories as its framework. Technological Determinism and Diffusion of Innovations. Technological Determinism originated from Thorstein Veblen (1857-1929) an American sociologist and economist . The first major elaboration of Technological Determinism view of socio-economic development came from the German philosopher and economist Karl Marx. He believed that technological progress leads to newer ways of production in a society and this ultimately influence cultural, political and economic aspects of a society thereby inevitably changing the society itself. This was further developed by Marshal McLuhan in 1964 (Asemah, Nwampo and Nkam-uwaoma ;2017). The justification for the use of this theory is that people are aware and knowledgeable of the robot technology but it would be easier for the society including procurement agents to accept and use the advertising automation tool artificial intelligence for procurement if the broadcast media adequately educate the society (Lukin;2018). Diffusion of Innovation is the study of how new ideas, practice, object etc. become known and accepted and are spread throughout a social system. It was introduced by Everett Rogers in 1983.

Rogers (1983) believes that new ideas that have greater relative advantage compatibility, trial, observation and less complexity would be adapted more rapidly than other innovations.

The effect of diffusion is that broadcast audience as part of a social system, adoption of the new ideas, products or behavior (innovation) do not happen simultaneously. Some members of the audience adopt the innovation faster than others in the process. Their categories are: innovators, early adopters, early majority, late majority and laggards. This theory is relevant to this study because Artificial Intelligence's Advertising Automation tool have become indispensable procurement bidding tool. The media understand the impact but need to educate the public more for the benefit of this digital age (Schaefer;2019).

Be that as it is, education on procurement bidding using A.I on broadcast platform of the radio and the television are of special relevance to Niger State and Nigeria as a whole. This is because of her precarious developmental position she occupies in this digital age. By any standards of reckoning, statistics for business expectancy for promotion of procurement bidding can only be stimulated by advertising on both, the radio and the television. Education, (Luckin;2018), using advertising automation tools can stimulate procurement bidding activities on customers to raise desired response, accept and purchase both products and services. This can attract high financial turn out and give bidders opportunity to see firsthand the benefits of being educated through advertising on the broadcast media. Added to this, advertising (communication through the media about products, service or ideas paid for by an identified sponsor) using A.I advertising automation tools have become an integral part of humanity's social and economic system in development. It has tremendously grew over the years to assume proportions as a business activity and as a social phenomenon. Adverts using Advertising Automation tools on the radio and the television can;

8. oil the wheels of the digital economy of the Minna Metropolis
9. explain how well procurement products and services are acquired and carried out,
10. up lift financial and infractural as well as service to move the Niger State forward,
11. provide information on products, services to better human lives.

Thus, a strong and an efficient advertising automation tool on radio and the TV can enable the state to adequately feed its growing population through its abundant land mass, generate employment through agriculture, earn both natural and foreign exchange and provide effective procurement biddings for all other sectors of the Niger State communities. However, inability of the broadcaster media to educate(Luckin;2018) the Niger people on the advantages of advertising automation tool of A.I on procurement bidding and how to take advantage of it in enhancing marketing communication (King, 2019) through the radio and TV can expose the state to an unhealthy economic future in this digital age.

Although scholars tend to conceptualize the digital age differently, such definition generally indicate that the concept connotes interactive communication among social groups. The underlining characteristic is that they are internet based application platforms which allow users to generate and exchange information contents (Kaplan and Heinlein 2010). They are therefore a form of communication system that enable users to be educated on-line with the assistance of the internet to share: news information, photos, ideas, thoughts or respond to issues such as advertisement of procurement bidding services. The term advertisement, Bovere and Arens (1984)

see advertisement as a non-personal communication of information usually paid for and usually identified with sponsors' through the various media. Advertising practitioners of Nigeria (APN) sees advertising as a form of communication through the media about products services or ideas paid for by an identified sponsor.

In consonance with this, procurement bidding its, marketing consultations recommends a two-way exchange of information and discussions ((educating) supply chain of products and services based on what is required(Sinha and Unemyr, 2019). This includes direct contact with potential bidders which in turn enables the procurement services to deepen its understanding of the state of the market. Thus more information and insight can enable the procurement units to have better outcome of specification for bidders of required procurement services and products. However, through education, market consultations can optimize procurement services from potential bidders. It can be base on the experiences of the procurement farmers, transparency, honesty and fair play (Belk;2016). This in turn ensures procurements' budgeting base on its objectives.

Added to this, the digital age is characterized by a collation of technologies and computer-mediated tools such as networking platforms, blogs, media, works, sharing tools and the virtual worlds which facilitates, educative interactions between people from diverse cultures and backgrounds in time and space (Kaplan and Haelein ;2010, Abubakar; 2011) examples of these technologies and computer medicated tools include: facebook, twitter, myspace, linkedin, you tube, flicker, slideshare, blogspot, google, myspace, skype, whatsapp, instagarm, flipagram, nimbuzz, 2go, it is and ultimately the artificial intelligence (A.I).Other features of the digital age which is a global excitement is the fact that robot machines perform advertising machines carry out ads campaigns with speed and precision.

A.I advertising automation tools in procurement processes aims to develop systems that exhibit human level intelligence and recreating super ability such as reasoning, learning and problem solving across procurement bidding. Advertising automation tools of A.I contributes to a better, more dynamic and adaptive procurement bidding processes which leads to friendlier procurement products, services and ideas. Automate bidding performances frees up time by taking care of more procurement routine tasks, as well as creative or strategic tasks like supplier relationship. Other tasks of A.I advertising automation tool include:

3. prediction advertising of procurement ideas, services and products
4. content generation of procurement bidding activities
5. location based targeting for procurement services
6. statement analysis for procurement and
7. advancement procurement and prediction of procurement bidding activities.

Thus A.I advertising automation tools are needed in procurement bidding activities for better supplier sourcing, negotiation and ongoing vendor scoring, contract and document management, cat -boats and digital assistance, preparing purchase order from approved purchase requisition as well as invoice processing automation (Boato and De Natale, 2020). This in turn stimulates procurement consumers to raise the desired responses in order to accept and purchase ideas, products and services of procurement.

Education on discussion of procurement bidding of A.I advertising automation tools on radio and the television are of special relevance to Niger state, given the precarious developmental position she occupies in the digital age for business expectancy. The state is behind other developing areas of the modern digital age. The raw wave of A.I industrialized and modernization being witnessed in the better developed areas of Nigeria has to be felt in this part of the North – Central Nigeria . The frustration exhibited by poor radio and television education in the benefits of using A.I. advertising automation tool in the present digital age can slipped the community into a bleak category of the 19th century. This is because the conception of development that underpinned usage of A.I. advertising automation tool on radio and T.V ads on procurement bidding is for maximization of purchase of goods, services and ideas of this digital age(Venkatesan and Lecinski, 2021).

A strong and efficient A. I's advertising automation advertising platforms on the radio and the T.V on procurement bidding can enable Niger State to feed its growing population, generate modern employments ,earn foreign exchange and provide effective procurement industry(Kotler,Kartajaya and Setiawan; 2020). Niger State is generously endowed with abundant natural resources as well as human resources. The A.I resources can be developed if the populace are properly educated and encouraged to take opportunity of this golden digital age. A.I resources serve the Nigerian economy (Olagide 2015). Beside oil, the major strength of the Nigerian economy, is A.I. rich digital resource base, its human resource and its huge markets. However, the economy of the state remains vulnerable to external, shocks emanating from fluctuation in the world of crude oil and rising prices of imports.

Equally important is the fact that human powered and conventional soft-ware based advertising system have been beaten by A.I's advertising automation tool because they operate largely with minimal human evolvment. This results in a more competitive advantage for businesses. A.I's advertising automation tool determines how ads on radio and Tv work and can even assist procurement bidders and biddings significantly because it enables decision related to logistic planning, assesses many different data sets simultaneously and brings up solution to issues for optimal values of all parties involved in procurement business activities(Lee, Javis and Herath, 2020).

Method:

This study adopted a combination of quantitative and qualitative sources of data gathering whereby the questionnaire was used to generate data. The universe of the population were residence of Minna metropolises but the target population were the staff of broad cast media of Tv and radio. The purposive sampling technique was used to select 400 respondents from both radio Niger and NTA Minna. The choice of the technique was to ensure that only broad cast media practitioners took part in the study. The questionnaire items were created from the research questions and hypothesis and were used to collect 385 respondents. Considering the knowledge of media practitioners on A.I. and its advertisement platforms, Radio Niger and NTA Minna were chosen as the study area. The choice of the radio and the television was informed by the fact that there are most used broad cast media in the state for procurement services. Staff of both radio and the television are active recipient of new media technologies of the digital age.

Respondents were sampled in their work places of both radio and the television stations in Minna. The questionnaire were structure in simple percentages were on the other hand, a test retest method was used within an interval of two weeks in both radio Niger and NTA Minna to test the reliability of the instrument.

An analysis of the reliability coefficient coefficient of the research instrument was computed to be 0.95 using Cronbach's Alpha technique. Thus, the instrument was accepted as a good one. The data collected were measured with the statistical package for social sciences (SPSS) version 20.0 in pursuit of central tendencies, deviations and their associated levels of significant differences. However the demographic data of the respondents were analyzed using frequency tables and percentages of for purposes of inference.

To complement the primary data the researcher consulted materials on A.I, procurement bidding and its advertisement on in published books journals conference and seminars, workshop papers, newspapers, magazines as could be found in the internet, private and public libraries.

Finding and Discussion

Demographic characteristics of the respondents. Table one provides information on the demographic characteristics of the sample. The samples contain more males than (37) females which is not surprising of advertising studies. Studies in the United States of America by Baran (1999:427) indicates that serious broadcast users tend to be male. In the same vein, most respondents who showed interest in A.I driven advertisement on procurement bidding in the broadcast Media in Minna were male.

Table One

Demographic characteristics of respondents

Variable/category	Frequency	Percentage
Gender: Male and Female	Male: 211	51.4%
Radio Niger: 113 and 85	Female: 174	48.6%
NTA Minna: 98 and 89		
Total	385	100%
Age Group		
25 years-35 years	197	51.2%
36 years-46 years	153	39.7%
46 years and above	35	9.1%
Total	385	100%
Education		
Secondary School	27	7%
Graduates	143	37%
OND, NCE and equivalent	174	45.2%
B.A, BSC, HND and equivalent	41	10.6%
Masters and above	385	100%
Total		
Rank of respondents in broadcast service		

Radio Niger: Senior Staff:	57:123	14.8%:31.9%
Junior Staff		
NTA Minna	62:143	16.1%:37.1%
Total		100%

Source: AI- driven education ads on procurement bidding in broadcasting platforms in Minna 2024.

The essence of the table above was to ascertain the gender, age group, education and occupational ranks of respondents which were familiar with A.I-driven education by advertisement on procurement biddings through the selected procurement biddings through the selected broadcast media platforms. It was discovered that then male, averagely educated, junior rank personnel of media and ages of personnel between 26 years and 36 years showed or interest in the study. This means that male respondents that showed interest in the study were 211 (51.4%) while the females were 174 (47.6%), ages between 25 years and 36 years had 197 (51.2%) 36 years to 46 years were 153 (39.7%) and the ages 45 and above were 35 (9.1%) that can enthusiastically have participated in the study. Educational level of respondents that eagerly participated were: 27 (7%), HND, OND and equivalent were 143 (37%) BSC, HND and equivalent were 174 (45.2%) and those with master's degrees and above were 41 (10.;6%) respondents.

Added to these, the professional ranks of the respondents were senior staff 119 () and for both Radio Niger and NTA Minna.

Table Two

Frequency of Radio Niger and NTA Minna in educating the public on A.I-driven ads on procurement biddings:

Radio Niger		
Frequency	Number	Percentage
Very Often	25	14%
Often	72	40.2%
Not Often	65	36.3%
Not at all	17	9.5%
Total	179	46.5%

NTA Minna		
Frequency	Number	Percentage
Very Often	36	17.5%
Often	31	39.2%
Not Often	63	30.6%
Not at all	26	12.6%
Total	206	53.5%
Grand Total	385	100%

Source: Table Two investigated the frequency at which Radio Niger and NTA Minna carry out advertisements of procurement biddings on the broadcast media.

From the questionnaire, items collected and analyzed, it showed that Radio Niger had very often 25 (14%) often 72 (40.2%) not often 65 (36.3%) and not at all 17 (9.5%). Additionally, NTA Minna had very often 36 (17.5%), often 81 (39.2%) Not often 63 (30.6%) not at all 26 (12.6%) This table shows that NTA Minna gives more frequency in educating the public on A.I-driven advertisement on procurement bidding on their media platform.

Table Three

Comparative patronage of A.I-driven advertisement in the broadcast media by procurement agents

Radio Niger		
Variable	Frequency	Percentage
Very Often	13	6.1%
Often	19	8.8%
Not often	78	36.3%
Not at all	105	48.8%
Total	215	

NTA Minna		
Variable	Frequency	Percentage
Very often	17	9.83%
Often	25	14.5%
Not often	78	45.02%
Not at all	53	30.06%
Total	173	
Grand total	385	100%

Source: Table three displays comparative patronage of A.I-driven advertisement in the broadcast platforms by procurement agents.

Radio Niger shows that the patronage recorded between the year 2023 to 2024 were very often 13 (6.1%) while NTA Minna was 17 (9.83%) often for Radio Niger was 19 (8.8%) while NTA Minna was 25 (14.5%) Not often for Radio Niger was 78 (36.3%) while NTA Minna was also 78 (45.02%) Not at all for Radio Niger patronage was 105 (48.8%)while that of NTA Minna was 53 (30.6%) The compression shows that NTA Minna received more patronage on A.I driven advertisement in the broadcast media by procurement agent in the 2023-2024 physical year.

Table Four

Challenges affecting A.I-driven ads-education on procurements bidding in the broadcast media.

Radio Niger		
Variable	Frequency	Percentage
3. Poor Edu-media Engagement	21	9.9%
3. Inappropriate Broadcast facility for A.I ads activities	33	15.57%

4. Dehumanization and destandardisation of traditional advertisement in journalism	23	10.8%
5. Manipulation of traditional advertisement in the digital age	45	21.23%
6. Poor Financial patronage	37	17.45%
7. Negative effects of interplay of digital media and citizen journalism in Niger State	33	15.57%
8. Fears of cybercrime to adjust to new technological changes.	22	10.38%
Total	212	100%

NTA Minna

Variable	Frequency	Percentage
4. Poor Edu-media Engagement	16	9.3%
9. Inappropriate Broadcast facility for A.I ads activities	22	12.7%
10. Dehumanization and de-standardization of traditional advertisement in journalism	18	10.4%
11. Manipulation of traditional advertisement in the digital age	32	18.5%
12. Poor Financial patronage	35	20.2%
13. Negative effects of interplay of digital media and citizen journalism in Niger State	31	17.9%
14. Fears of cybercrime to adjust to new technological changes.	19	10.98%
Total	173	100%

Source: Table three displays comparative patronage of A.I-driven advertisement in the broadcast platforms by procurement agents.

Table Four displays challenges faced by both Radio Niger and NTA Mina in usage of A.I-driven education on procurement bidding activities in the year 2023-2024. Radio Niger shows that poor Edu-media engagement was 21 (9.9%) while 16 (9.3%) Inappropriate broadcast facilities was 33 (15.57%) for Radio Niger and and 22 (12.7%) for NTA Minna. Dehumanization and de-standardization of traditional ads was 23 (10.8%) for Radio Niger but 18(10.4%) for NTA Minna. Manipulation of traditional media advertisement in the digital age for Radio Niger was 45 (21.33%) and 32 (18.5%) for NTA Minna.

Poor Financial patronage was 37 (17.45%) for Radio Niger and 35 (20.2%) for NTA Minna negative effects of interplay between digital media and citizen journalism for Radio Nigeria 33 (15.57%) found 31 (17.9%) for NTA Minna. Fear of Cybercrime to adjust to now technology fo Radio Niger was 22 (10.38%) and 19 (10.98%) for NTA Minna. The implication of these schools shows that the NTA Minna gets more patronage on A.I driven advertisement on procurement biddings than the Radio Niger.

Table Five

Responses on the extent broadcast media use A.I – driven ads for marketing communication in procurement biddings

Radio Niger		
Variable	Frequency	Percentage
Positive	97	48.3%
Negative	93	46.3%
Can't tell	11	5.47%
TOTAL	201	100%

NTA Minna		
Variable	Frequency	Percentage
Positive	113	61.40%
Negative	64	34.8%
Can't tell	07	3.80%
TOTAL	184	100%

Source: Table three displays comparative patronage of A.I-driven advertisement in the broadcast platforms by procurement agents.

Table five shows extend the broadcast media using A.I – driven ads for marketing communication in the year 2023/2024. Positive variable for radio Niger was 97 (48.3%) and 113 (61.40%) for NTA Minna. Negative variable for Radio Niger was 93 (48.3%) and that of the NTA was 64 (34.8%) can't tell variable for Radio Niger was 11 (5.47%) and 7 (3.80%) for NTA Minna

TEST OF HYPOTHESES

Table Six

Chi-square test analysis of the relationship between exposure to A.I – driven education advertisement on the broadcast media and procurement activities in Minna.

Grouping	X² cal	df	Decision
Exposure to A.I – driven Ads education on procurement bidding	210.102	4	Sig

Source: Table three displays comparative patronage of A.I-driven advertisement in the broadcast platforms by procurement agents.

The results from the table above reveals that the calculated X² value (210.102) is greater than the critical value (3.841) at 4 degree of freedom (D.F) and 0.05 confidence level. The second null hypothesis is therefore rejected. The implication is that there is no significant statistical

relationship between exposure to A.I – driven education advertisement on the broadcast media and procurement activities in Minna.

Table Seven

Chi-square test analysis of the relationship between exposure to A.I – driven education advertisement on the broadcast media and procurement activities in Minna.

Grouping	X² cal	df	Critical value	Decision
Exposure to A.I – driven Ads education on procurement bidding	210.102	4	3.841	Sig

Source: Table three displays comparative patronage of A.I-driven advertisement in the broadcast platforms by procurement agents.

The results from the table above reveals that the calculated X² value (210.102) is greater than the critical value (3.841) at 4 degree of freedom (D.F) and 0.05 confidence level. The second null hypothesis is therefore rejected. The implication is that there is no significant statistical relationship between exposure to A.I – driven education advertisement on he broadcast media and procurement activities in Minna.

Discussion of Findings

This chapter examined usage of A.I – driven education on advertisement of procurement biddings in both Radio Niger and NTA Minna media platforms from September 2023 to August 2024. Some of the outcomes revealed that the younger age of; 25years – 35 years, educated (BA, B.Sc. and equivalent) and the junior rank of the media personnel participated more eagerly in the study in table one. Table two shows that NTA Minna comparatively had more frequency in educating the populace in A.I. - driven ads on procurement biding and equally had better patronage in table three. Table four shows the various challenges that the two broadcast media that use A.I – driven ads on procurement biddings. The major issue on; manipulation of traditional Media ads, poor financial patronage and negative effects of the interplay of digital media as well as netizen journalism in both Radio Niger and NTA. Minna. This result is consistent with William (2008) that humans increase dependence on technological shelter may lead to the weakening of human interdependence which is another source of insecurity:

Our environment will inevitably become less natural; the question is whether It will become less human if we allow technology to take over our surrounding. They can become in hospital to human life. pp,213. Usage of A.I.-driven ads education for marketing communication is vital in this digital age. The results show positive outcome even though the physical manifestation is slow. This finding is in consonance with the importance of this computer age because there will soon be a digital revolution which will be characterize by A.I. features.This is the right time to get use to robotic automation machine for the incoming A.I. era (Bharradwag&Noble;2019) .

Additionally, the staff of the broadcast media show good knowledge of A.I. automation tool for ads in their marketing communication of procurement products and services. How, the results show that even though larger showed interest and eagerness in knowledge of A.I. the patronage

of procurement services, products and education of the A.I. automation machine in marketing communication for ads is pathetic even though the hypotheses show high relationship(Chung,&m;2020).

Conclusion

Many researchers of artificial intelligence are of the view that A.I. automation for ads in the broadcast media have numerous benefits with few challenges. However, Radio Niger and NTA Minna have not carried out enough education on A.I. nor on A.I. automation tool for ads in procurement bidding activities in the year 2023-2024 in Niger state. The two broadcast media staff interviewed as well as the results received from the questionnaire items of research questions about their knowledge and information on artificial intelligence obtained them through the media. This reinforces the fact that communication is powerful particularly in the new media in disseminating of information in marketing communication.

Recommendations

1. Both Radio Niger and NTA Minna should disseminate information regularly in the area of artificial intelligence and its automation ads tool to reach potential procurement bidders, institutions, organizations, and the entire society
2. Most people in the society obtain information and knowledge about technology from the broadcast media ,there need to be more disscusions, talks and education through the media on A.I.in general as well as specifying on education of A.I. automation tool for ads on procurement services.
3. The government of the state should play a major role of encouraging the people into features of the computer age of artificial intelligence. This, can be done by sending staff on training, conducting in-service trainings, seminars and workshops on knowledge and applications of A.I. benefits to everyday life as well as purchase and use of automation tool of ads in the broadcast media for mutual benefits of both the government and the people.
4. Media staff in the communication industry should not be afraid of losing their jobs as A.I. robots rather enhance their efficiency in broadcast media professionalism.
5. Media workers and authorities should embark on a more creative ways of creating awareness on the need of A.I.in this digital age and how people can take advantages of it to make our world a better place for living.
6. The media should carry out regular discussions on A.I. tool for ads in marketing communication to dispel misconceptions on the evils of A.I. technology.

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INTEGRATING THE KNOW-WANT-LEARN (KWL) STRATEGY INTO GEOMETRY TEACHING: A PATHWAY TO IMPROVED PERFORMANCE AND RETENTION AMONG UPPER-BASIC STUDENTS

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Abstract

the persistent underperformance of students in geometry has generated concern among educators and policymakers in Nigeria and beyond. Despite numerous curriculum reforms, teaching methods often remain teacher-centred and procedural rather than conceptual. This opinion paper argues for the systematic integration of the Know–Want–Learn (KWL) strategy into geometry instruction as a means of enhancing students’ engagement, conceptual understanding and retention. It highlights the strategy’s potential to promote active learning, reflective thinking and metacognitive development among upper-basic students. The paper also presents a contextualised framework for implementing the KWL strategy in Nigerian classrooms and discusses its implications for curriculum design, teacher professional development and educational research. By positioning learners as active constructors of knowledge, the paper advocates for a shift from rote memorisation to meaningful, self-directed learning that fosters long-term achievement and retention in geometry.

Keywords: *Know–Want–Learn (KWL) strategy, geometry teaching, student performance, retention, metacognitive learning, active learning, upper-basic education and mathematics instruction*

Introduction

Geometry is a foundational branch of mathematics that equips learners with spatial reasoning, logical thinking and problem-solving abilities. However, persistent reports of poor achievement in geometry among upper-basic students suggest that traditional methods of instruction are failing to address conceptual understanding. Teachers often rely on rote memorisation, rule-based demonstration and note-taking, while students remain passive recipients of knowledge. The consequence is a fragile understanding that fades shortly after assessment, leading to weak retention and low motivation.

The Know–Want–Learn (KWL) strategy, originally developed by Ogle (1986), offers an instructional shift that foregrounds learner engagement and reflection. It prompts students to activate prior knowledge (K), set learning goals (W) and reflect upon acquired understanding (L). By aligning with constructivist and metacognitive learning theories, the KWL framework encourages students to see learning as a self-regulated and meaningful process.

In the Nigerian upper-basic context typically comprising students aged 11 to 14 such a reflective and participatory approach could transform geometry learning from a task of memorisation to one of exploration and personal growth. This opinion paper therefore advocates for a deliberate

integration of the KWL strategy into geometry classrooms to improve students' performance and retention.

Understanding the KWL Strategy: Theoretical and Pedagogical Foundation

The KWL strategy rests upon two interconnected pedagogical theories: **constructivism** and **metacognition**. Constructivism posits that learners actively build knowledge through experience and reflection, rather than passively absorbing information. Metacognition, on the other hand, involves learners' awareness of their own thought processes knowing what they know, what they need to know and how they can learn it effectively.

By asking learners to identify what they already *Know*, the KWL chart activates prior knowledge and allows teachers to assess students' entry points. The *Want* column stimulates curiosity, setting personalised learning objectives that create intrinsic motivation. Finally, the *Learn* column promotes reflection, enabling students to consolidate and evaluate their understanding.

As Bogdanović *et al.* (2022) demonstrated in physics instruction, this metacognitive process significantly enhances students' capacity to monitor their learning progress and transfer conceptual understanding across contexts. The implication is clear: in geometry where abstract reasoning and visualisation are critical the KWL structure can scaffold students' thinking from the concrete to the abstract.

The Challenge of Geometry Learning in the Upper-Basic Classroom

Geometry often poses cognitive and affective challenges for students. The abstraction of geometric shapes, symbols and theorems requires learners to mentally visualise and manipulate figures—skills that many students find difficult. Danlami *et al.* (2024) observed that in Kaduna North, Nigeria, students' poor retention in geometry was closely linked to the overreliance on lecture methods and the lack of opportunities for self-regulated learning.

Furthermore, cultural attitudes toward mathematics as a 'difficult subject' amplify anxiety and discourage exploration. Many teachers, constrained by examination-oriented systems, prioritise coverage of syllabus over comprehension. The result is an educational paradox: students may memorise formulae but fail to apply them meaningfully.

Integrating the KWL strategy within this context introduces a shift in classroom culture. Instead of dictating knowledge, teachers become facilitators guiding students to connect new geometric ideas to their lived experiences. For instance, before teaching "Properties of Triangles," students could brainstorm what they *know* about triangles from daily objects, identify what they *want* to discover (e.g., "How do we know when a triangle is right-angled?") and finally reflect on what they *learned* after exploration. Such cycles transform learning into an inquiry-driven experience.

Evidence from Empirical Studies Supporting the KWL Strategy

Although this paper presents a conceptual argument rather than new data, it draws upon a strong body of empirical evidence supporting the KWL approach across disciplines.

In Mathematics Education

Aseeri (2020) found that Saudi high school students exposed to the KWL strategy showed significantly higher achievement and motivation in mathematics compared to those taught through

traditional methods. The interactive structure of KWL was shown to reduce cognitive overload by allowing learners to process information in stages linking prior and new knowledge sequentially.

Similarly, Fagunwa (2022) demonstrated that primary pupils in Kwara State who learned literacy skills through the KWL method exhibited improved comprehension and recall. Though the subject differed, the cognitive principles are transferable to geometry: breaking down complex information into meaningful, learner-generated categories enhances retention.

In Science and Social Studies

Alsalhi (2020) provided compelling evidence from the domain of science education, reporting that KWL improved both achievement and attitudes among fourth-grade students. Likewise, Soberekon and Brown (2019) found that combining KWL with cooperative learning in Social Studies led to superior performance and engagement. The researchers concluded that the differentiation enabled by KWL accommodated varying learner abilities—a feature particularly relevant in Nigeria’s heterogeneous classrooms.

In Metacognitive Development

Bogdanović *et al.* (2022) extended the analysis by showing that a modified KWL strategy in physics not only enhanced achievement but also promoted metacognitive growth. Students became more conscious of their thought processes, planning strategies and self-assessment skills. These outcomes reinforce the assertion that KWL cultivates learners who are reflective and autonomous—qualities essential for mastering geometry’s abstract nature.

In Geometry Retention

Danlami *et al.* (2024) provided direct evidence of the effectiveness of KWL in geometry learning among Nigerian upper-basic students. Their findings revealed a significant improvement in retention compared to those taught conventionally. The study highlighted the importance of connecting pre-existing spatial knowledge with formal geometric principles. Likewise, Kebin (2024), though focusing on the origami strategy, confirmed that learner-centred, hands-on approaches substantially improve geometry retention—aligning with KWL’s core principle of active engagement.

Integrating the KWL Strategy into Geometry Teaching

For the KWL strategy to be successfully integrated into geometry classrooms, certain pedagogical and institutional adjustments are necessary. The following framework outlines how teachers can adapt the approach effectively:

Pre-Lesson Stage: Activating Prior Knowledge (K)

Teachers begin by engaging students in discussion or brainstorming activities about the topic. Visual aids, real-life examples, or manipulative objects may be used to elicit what students already know. For instance, in teaching “Angles and Parallel Lines,” learners could be asked to describe where they have seen such patterns in everyday life (e.g., roads, roofs, or window frames). This stage establishes a foundation upon which new knowledge can be built.

Lesson Stage: Setting Learning Goals (W)

Students identify what they *want* to learn. This transforms them from passive listeners to active goal-setters. Teachers should encourage questions like “Why are alternate angles equal?” or “How can I calculate missing angles using only one given value?” These inquiries drive intrinsic motivation and sustain engagement throughout the lesson.

Post-Lesson Stage: Consolidating Knowledge (L)

After exploration, students reflect and summarise what they have learned. This may be done through group presentations, journals, or self-assessment charts. Reflection not only reinforces learning but also makes teachers aware of misconceptions or areas requiring reinforcement.

Integrating technology—such as interactive geometry software or digital KWL templates—can further enhance this process, providing visualisation and immediate feedback.

Implications for Teachers, Curriculum Designers and Policymakers**For Teachers**

Teachers need targeted professional development to implement KWL effectively. Training should focus on facilitation skills, questioning techniques and formative assessment methods. Shifting from a lecture-based to a learner-centred mindset requires both conceptual and attitudinal change. Teachers should also be encouraged to integrate KWL with other strategies, such as inquiry-based and cooperative learning, to maximise its potential.

For Curriculum Designers

Curriculum frameworks should embed reflective learning structures like KWL in lesson objectives and assessment tasks. This ensures consistency between instructional goals and classroom practice. Furthermore, textbooks and teaching guides should provide exemplars of KWL integration in geometry topics.

For Policymakers

Educational policymakers should promote evidence-based instructional innovation through funding, teacher workshops and continuous monitoring. Incorporating KWL into national teacher training programmes would foster a culture of reflective pedagogy aligned with 21st-century skills.

Conclusion

The Know–Want–Learn (KWL) strategy transcends its role as a mere instructional technique to embody a holistic philosophy of learning that empowers students to take active ownership of their understanding. Within the challenging domain of geometry—where abstraction, reasoning and retention often hinder achievement—KWL offers a dynamic, learner-centred framework that transforms passive reception into purposeful exploration. By prompting learners to activate prior knowledge, articulate learning goals and engage in reflective evaluation, the strategy bridges the persistent gap between rote memorisation and genuine conceptual mastery. Empirical evidence across disciplines consistently attests to its capacity to enhance performance, motivation and long-term retention. Therefore, integrating the KWL approach into upper-basic geometry instruction stands as a potent avenue for nurturing higher-order thinking and sustained engagement. Ultimately, the path to enduring improvement in mathematics education depends not merely on curriculum content but on the transformative pedagogy that inspires learners to *know*, *want* and *learn* the true essence of meaningful and lifelong education.

Recommendations

1. **Teacher Professional Development:** Teachers should be systematically trained on how to effectively implement the KWL strategy in geometry instruction. Such training should focus on lesson planning, questioning techniques, scaffolding inquiry and guiding reflective discussions to ensure the strategy becomes an integral part of daily classroom practice rather than an occasional activity.
2. **Curriculum Integration:** Curriculum developers should embed the KWL framework within geometry syllabuses, instructional guides and textbooks. Each topic should include prompts or templates that help students articulate what they already know, what they seek to learn and what they have understood, thereby promoting active engagement and deeper conceptual learning.
3. **Instructional Innovation and Resource Support:** School administrators and policymakers should provide teachers with instructional resources such as digital KWL charts, manipulatives and visual aids that make geometry concepts more tangible. Encouraging the use of technology-enhanced versions of the KWL strategy—such as interactive whiteboards or learning management systems—can further enrich students’ experiences and outcomes.
4. **Further Research and Continuous Evaluation:** Researchers and education stakeholders should conduct longitudinal and mixed-method studies to examine the long-term impact of the KWL strategy on students’ geometry achievement, retention and motivation. Continuous monitoring and evaluation of classroom implementation will also help refine best practices and ensure sustainability across diverse educational contexts.

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ARTIFICIAL INTELLIGENCE-DRIVEN EDUCATIONAL TECHNOLOGY FOR AN INNOVATIVE WORKFORCE

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Abstract

This study investigates how AI-driven educational technologies can foster an innovative workforce by enhancing learners' skills, creativity, and readiness for industry. Three research questions guided the study. A descriptive survey research design with a cross-sectional approach was adopted. The study was conducted in Abuja and Minna. The population comprised 200 postgraduate and final-year undergraduate students enrolled in STEAM and education technology programs in Nigeria. A 15-item structured questionnaire aligned with the research objectives was used for data collection. The instrument was validated by experts in curriculum development, technical education, and educational technology. The reliability coefficient of the instrument was 0.86. Data were collected physically through hand delivery method and electronically using Google form. All administered questionnaires were retrieved, yielding a 100% response rate. Data were analyzed using mean and standard deviation. The findings showed that strong positive perceptions of AI's educational value, evidence of gains in learners' innovation readiness, and barriers in infrastructure and faculty training. Strategies identified included capacity-building, policy development, infrastructure provision, and pilot projects. The study recommends capacity building for educators, phased AI adoption strategies, invest in infrastructure and resource mobilization, secure funding for computing resources, reliable connectivity, and technical support, as well as policies to sustain AI initiatives beyond pilot phases.

Keywords: Artificial Intelligence, Educational Technology, Workforce Innovation

Introduction

AI-driven educational technologies (edtech) include systems like adaptive learning platforms, intelligent tutoring systems, predictive analytics, and virtual assistants. These tools can continuously monitor learner performance, provide real-time feedback, and tailor content to individual needs. The promise is that learners graduate not only with knowledge but with practical, innovation-oriented skills. The link between AI adoption in firms and greater demand for technically skilled workers further underscores the urgency of aligning education with workforce needs (Brookings, 2025). In recent years, artificial intelligence (AI) has been progressively integrated into educational systems, enabling more adaptive, personalized, and intelligent learning experiences (Wang *et al.*, 2024). Such AI-based education systems are now being considered not merely as pedagogical tools but as strategic enablers of workforce development and innovation. As the nature of work evolves, educational institutions must equip learners with competencies—such as creativity, problem solving, and adaptability—that align with a rapidly changing labor market.

Artificial Intelligence (AI) refers to systems or machines that mimic human intelligence to perform tasks such as learning, reasoning, and decision-making (Russell & Norvig, 2020). In the context

of vocational education, AI has the potential to transform instructional delivery by enabling adaptive learning, automating assessment, and enhancing digital access to quality training. For innovative workforce, AI tools can provide scalable solutions to teacher shortages, improve training quality, and simulate real-world scenarios that enhance skill acquisition (Luckin *et al.*, 2016). However, to fully prepare learners for the future economy, integrating AI must go hand-in-hand with intelligence driven technology.

However, the integration of AI in education is not without challenges. Ethical concerns, algorithmic transparency, equity, and lack of faculty competence are recurrent constraints in literature (Ifenthaler *et al.*, 2024). Moreover, many studies are conceptual or small scale; rigorous empirical investigations in African or developing-country contexts remain scant. There is thus a gap in understanding how AI-driven edtech functions as a lever for workforce innovation in such settings. This paper addresses that gap by conducting an investigation among higher education students in Nigeria. It examines their perceptions of AI edtech, the degree to which such tools enhance innovation readiness, and the institutional enablers or barriers. The goal is to derive practical implications for policy, pedagogy, and technology deployment.

Statement of the Problem

The global economy is increasingly demanding a workforce that is not just technically literate but capable of constant innovation and adaptation. Traditional educational models, which emphasize rote learning and standardized curricula, struggle to produce graduates equipped for such futures. Without intentional integration of cutting-edge technologies, there is a risk that graduates will lag behind industry demands (Adefeso-Olateju *et al.*, 2022). Though AI-driven educational technologies promise personalized learning and accelerated skill acquisition, their adoption is uneven, particularly in resource-constrained contexts. Many institutions lack infrastructure, faculty capacity, or strategic direction to embed AI into teaching and learning. As a result, learners may not fully benefit from the potential of AI to foster innovation and workforce readiness (Nwogu & Yusuf, 2021).

This persistent misalignment is largely attributed to the lack of strategic integration of AI tools and innovative competencies within the technical and vocational education and training (TVET). Although some interventions have sought to address these gaps — including pilot digital literacy projects, curriculum reviews, and digital workforce initiatives — these efforts have remained fragmented, donor-driven, or insufficiently institutionalized (ILO, 2019; Oviawe, 2021). For over a decade, researchers and policy actors have raised concerns about the relevance of TVET curricula to national and global development goals (Okolie *et al.*, 2019). Yet, the lack of coherent strategies for embedding AI edtech skills into vocational programmes has persisted. As a result, many graduates remain unprepared for the digital and innovative workforce, leading to skill mismatches, reduced employability, and missed opportunities for innovation. Empirical evidence on outcomes of AI in education is more robust in Western and Asian settings, but scant in many parts of Africa (Okolie *et al.*, 2019). This dearth limits understanding of contextual constraints—such as electricity, internet connectivity, and institutional culture—and makes generalizations precarious. Thus, there is a pressing need to investigate how AI-based edtech can effectively drive workforce innovation in contexts like Nigeria.

Aim and Objectives of the Study

The aim of the study is to examine the role of AI-driven educational technology in cultivating an innovative workforce among higher education students. The following objectives guide the study:

1. To assess learners' perceptions of usefulness, ease of use, and adoption of AI edtech.
2. To evaluate the impact of AI edtech on students' innovation readiness, creativity, and skill acquisition.
3. To identify institutional enablers and challenges in deploying AI edtech for workforce development.

Research Questions

The following research questions were raised and answered

1. What are learners' perceptions of AI-driven educational technologies in terms of usefulness ease of use, and adoption?
2. To what extent does exposure to AI edtech influence learners' innovation readiness, creative problem solving, and skill acquisition?
3. What institutional factors (enablers and barriers) affect the effective deployment of AI edtech in preparing an innovative workforce?

Methodology

This study adopted a quantitative survey research design with a cross-sectional approach. This design was considered appropriate for obtaining detailed and current information on the AI edtech, and strategies related to the integration of AI edtech. skills in Nigeria. The cross-sectional nature allowed for data collection at a single point in time, capturing the perceptions of relevant stakeholders within the innovative workforce system (Creswell, 2023). The area of the study comprised Abuja and Minna. Abuja was selected because it hosts notable AI edtech hubs and institutions of learning using AI driven technology. Minna was chosen because it has also institutions of learning and graduates spread across all its area using AI edtech, making it an ideal location to capture diverse institutional perspectives. The target population consisted of 200 students in STEAM and educational technology programs across two universities in Nigeria. Given the manageable size of the population, the entire group was studied without sampling to ensure comprehensive coverage and accuracy of findings.

Data were collected using a structured questionnaire comprising 15 items, distributed across three sections in line with the research objectives. The items were rated on a 5-point Likert scale, ranging from Strongly Disagree (1) to Undecided (5). The instrument was subjected to face and content validation by three experts in curriculum development, technical education, and educational technology. The reliability of the instrument was determined using Cronbach's Alpha, yielding a coefficient of 0.86, which indicates high internal consistency (Tavakol & Dennick, 2021). Data were collected physically through hand delivery method and electronically using Google form. All administered questionnaires were retrieved, yielding a 100% response rate. Data collected were analyzed using descriptive statistics, specifically, mean and standard deviation to address the research questions and provide a clear understanding of stakeholder perspectives.

Results:**Research Question 1**

What are learners' perceptions of AI-driven educational technologies in terms of usefulness ease of use, and adoption? Results for answering research question one is presented in Table 1.

Table 1: Average mean and standard deviation for the responses of the respondents on learners' perceptions of AI-driven educational technologies in terms of usefulness ease of use, and adoption

S/N	Items	Mean	SD	Decision
4.	AI edtech improves personalized learning	4.02	1.01	Agreed
5.	AI tools are easy to use in coursework	3.98	1.08	Agreed
6.	AI systems integrate smoothly with LMS	4.12	.98	Agreed
7.	Exposure to AI makes me more adaptive	4.06	1.01	Agreed
8.	I intend to adopt AI tools for learning	3.99	1.04	Agreed
	Grand Mean	4.03	1.02	Agreed

Table 1 reveals mean scores ranging from 3.98 to 4.12 and standard deviations between 0.98 and 1.08. These values indicated a strong existing learners' perceptions of AI-driven educational technologies in terms of usefulness ease of use, and adoption

Research Question 2

To what extent does exposure to AI edtech influence learners' innovation readiness, creative problem solving, and skill acquisition? A result for answering research question two is contained in Table 2.

Table 2: Average mean and standard deviation for the responses of the respondents on the exposure to AI edtech influence learners' innovation readiness, creative problem solving, and skill acquisition

S/N	Items	Mean	SD	Decision
5.	AI edtech enhances creative problem solving	4.09	1.08	Agreed
6.	I feel more prepared for tech-driven work	4.11	1.11	Agreed
7.	AI tools help me develop higher-order skills	4.17	1.02	Agreed
8.	Exposure to AI makes me more adaptive	4.07	1.05	Agreed
9.	AI edtech broadens my innovation mindset	4.00	1.02	Agreed
	Grand Mean	4.09	1.06	Agreed

Table 2 reveals mean scores ranging from 4.00 to 4.17 and standard deviations between 1.02 and 1.11. These values indicated a strong agreement among respondents on the exposure to AI edtech influence learners' innovation readiness, creative problem solving, and skill acquisition

Research Question 3

What institutional factors affect the effective deployment of AI edtech in preparing an innovative workforce? Results for answering research question three is presented in Table 3.

Table 3: Average mean and standard deviation for the responses of the respondents on institutional factors affect the effective deployment of AI edtech in preparing an innovative workforce

S/N	Items	Mean	SD	Decision
12.	Institution provides AI infrastructure	4.21	1.02	Agreed
13.	Faculty are trained in AI pedagogy	4.18	1.08	Agreed
14.	There is administrative support for AI projects	4.11	1.16	Agreed
15.	Funding is available for AI initiatives	4.06	1.18	Agreed
16.	Policy frameworks encourage AI in curriculum	4.17	1.22	Agreed
	Grand Mean	4.15	1.13	Agreed

Table 3 reveals mean scores ranging from 4.06 to 4.21 and standard deviations between 1.02 and 1.22. These values indicated that the respondents strongly support that institutional factors affect the effective deployment of AI edtech in preparing an innovative workforce

Findings:

1. Learners hold positive perceptions of AI edtech, strong positive perceptions of AI's educational value, evidence of gains in learners' innovation readiness.
2. The exposure to AI is strongly associated with enhanced innovation readiness and higher-order skills infrastructure and faculty training.
3. Institutional support is uneven: only a subset of items administrative support, policy frameworks, funding, and faculty training

Discussion

Findings on the learners' perceptions of AI-driven educational technologies in terms of usefulness ease of use and adoption revealed positive perceptions of AI's educational value, evidence of gains in learner's innovation readiness were not a constraints. This is in line with the findings of Okolie *et al.* (2020), who noted that the acceptance of items like "AI tool intention to use" suggests alignment with Technology Acceptance Model tenets regarding perceived usefulness and ease of use. This bodes well for adoption, but the rejection of seamless integration with LMS signals areas for technical refinement and system interoperability.

Similarly, UNESCO (2019) emphasized that policy ambiguity and resistance to change hamper the adaptation of innovative content in STEAM globally. However, unlike other studies such as Aina (2022), which reported infrastructural constraints as the most prominent challenge, the current study highlights teacher-related and structural issues as the most critical barriers. This difference may be influenced by the increasing push for digital and innovative workforce integration in education which puts pressure on institutional readiness rather than just financial availability. The implication of these findings is that without targeted interventions to build capacity, upgrade infrastructure, sensitize stakeholders, and develop enabling policies, the AI edtech. and innovative workforce skills in STEAM may remain aspirational in Nigeria.

A finding on the demonstrated boost in innovation readiness and skills is encouraging. The creative problem solving, adaptability, and higher-order skills suggest that students believe AI edtech contributes substantially to workforce preparedness. This aligns with arguments that AI in education should not simply transmit content but actively scaffold innovation competencies

(Giannakos et al., 2024) This supports the position of Yusuf and Afolabi (2021), who emphasized that institutional support and international collaboration are central to educational innovation in sub-Saharan Africa. Compared to the study by Ezeani and Nwachukwu (2019), which focused mainly on curriculum review as an enabler, the current findings offer a broader view by incorporating external partnerships and teacher motivation as significant catalysts. This broader perspective may be attributed to increasing global attention on edtech and digital transformation, which now directly influence national education agendas. The implication of these findings is that policymakers and institutional leaders must harness these innovative driven reform, with special emphasis on enhancing institutional motivation.

Findings on the institutional challenges loom large. The rejection of items related to infrastructure, faculty training, and funding points to real bottlenecks in many contexts. Even though administrative support and policy frameworks scored acceptably, without tangible resources and capacity building the potential of AI will remain under realized. This is consistent with broader concerns about equity, ethics, and resource constraints in deployment of AI in education (Ifenthaler et al., 2024). Capacity-building programmes, developing a policy framework, providing digital infrastructure, and encouraging pilot projects are essential approaches. This aligns with the recommendations of the NBTE (2021), which advocate for continuous professional development and innovation for Nigerian vocational institutions. While studies such as those by Iroegbu and Adebayo (2020) focused largely on curriculum review as a strategy, this study presents a more comprehensive suite of actionable strategies. This difference is likely influenced by the multidimensional nature of AI and green skills, which require systemic adaptation beyond curricular changes alone. The implication of these findings is that successful integration of AI and edtech will depend on a coordinated strategy involving teacher development, infrastructure investment, policy alignment, and innovation support across STEAM institutions.

Conclusion

This study indicates that AI-driven educational technologies hold promise in shaping an innovative, workforce-ready student body: learners are positively disposed to such tools, and many believe their exposure fosters higher-order skills and innovation readiness. However, institutional readiness—particularly infrastructure, training, and funding—lags behind. Without concerted investment and capacity building, the transformative potential of AI in education may falter.

Recommendations

1. Capacity building for faculty and administrators, institutions should implement ongoing professional development that equips educators to integrate AI pedagogically, interpret analytics, and supervise AI-augmented instruction.
2. Incremental and phased AI deployment, adopt a staged model beginning with pilot projects and scalable modules, ensuring compatibility with existing LMS and curriculum before wide scale rollout.
3. Invest in infrastructure and resource mobilization, secure funding for computing resources, reliable connectivity, and technical support, as well as policies to sustain AI initiatives beyond pilot phases.

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ENHANCING RETENTION IN AGRICULTURAL SCIENCE: A REVIEW OF THE ROLE OF INTERACTIVE LEARNING MODELS

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Abstract

Teaching agricultural science in developing contexts poses considerable challenges, especially when students must grasp complex biological processes such as the ruminant digestive system. Conventional lecture-based methods often fail to foster deep understanding or long-term retention because they rely on passive learning and limited visualization. This review examines the effectiveness of interactive learning models—including three-dimensional (3D) digital simulations and low-cost physical models—in enhancing comprehension and retention among agricultural science students. Drawing on empirical evidence and key pedagogical theories such as Cognitive Load Theory, Constructivist Learning Theory, and Dual Coding Theory, the paper highlights how interactive models reduce mental overload, promote active engagement, and enable students to construct and retain knowledge more effectively. Studies indicate that students exposed to interactive models demonstrate stronger conceptual understanding, better recall, and greater enthusiasm for learning compared with those taught through traditional approaches. Digital 3D models allow learners to visualize internal structures dynamically, while physical models, particularly those made from inexpensive local materials, provide accessible alternatives for resource-limited schools. Despite challenges such as cost, teacher training requirements, and time constraints, both approaches offer significant pedagogical value. The review concludes that integrating interactive learning models into agricultural science curricula can substantially improve students' retention, comprehension, and ability to apply knowledge in practical agricultural contexts. It recommends further research into the long-term impact of interactive models on students' professional competence and comparative analyses between digital and physical tools to guide policy and curriculum development in agricultural education.

Keywords: *Agricultural science, Interactive learning, Retention, Ruminant digestive system, Constructivist learning, educational innovation*

Introduction

Teaching agricultural science, especially in developing countries, can be tough. Many students struggle to understand complex biological systems, and traditional methods like lectures just don't cut it. Take the ruminant digestive system, for example—comprising the rumen, reticulum, omasum, and abomasum. It's one of the most challenging topics for students, as it involves intricate biological processes that are hard to visualize. To overcome this, interactive learning models—from 3D digital simulations to hands-on physical models—provide a powerful solution. These tools not only engage students but help improve their retention of challenging concepts. This article explores how these interactive models can improve retention in agricultural science, with a special focus on the ruminant digestive system.

Challenges in Retention and Comprehension of Agricultural Science Concepts

Retention of knowledge remains a major obstacle in agricultural science education. Subjects like the ruminant digestive system, which involve abstract biological processes, are especially difficult

for students to understand through traditional chalk-and-talk methods or text-based learning. Okafor & Nnadi (2020) pointed out that without the ability to visualize or engage with these concepts physically, students often struggle to retain them for practical use, particularly when it comes to applying knowledge in real-world agricultural settings such as livestock management. As Yusuf & Fawehimi (2019) noted, interactive learning—which involves tactile and visual experiences—helps students process complex information by reducing cognitive overload. Interactive models make abstract ideas more concrete, allowing students to form mental pictures of complex processes. This leads to better retention and a deeper understanding of the material.

Interactive Learning Models: A Solution to Enhance Retention

Interactive models are revolutionizing how agricultural science is taught. Whether 3D digital simulations or physical models, these tools let students get hands-on with the material, which is something traditional methods cannot provide. For instance, a 3D model of the ruminant digestive system allows students to explore the four stomach compartments, visualize the digestive process, and even manipulate the components of the system. This type of active involvement significantly enhances retention and understanding (Yusuf & Fawehimi, 2019). In Nigerian schools, a study demonstrated how 3D models helped secondary school students better understand the ruminant digestive system. Those who worked with the 3D models performed better on exams, showcasing a clearer understanding of how food moves through the digestive system, compared to students who were taught using traditional methods (Yusuf & Fawehimi, 2019). Physical models made from low-cost materials—such as clay, cardboard, or plastic—are just as effective, especially in resource-limited environments. These models allow students to physically engage with the digestive system, helping them trace the path of food through each stomach compartment. Suleiman & Abdulkareem (2024) highlight that, although these low-cost models may not have the sophistication of digital ones, they still provide the same valuable hands-on experience that enhances retention.

Example of Low-Cost Models

In rural schools across Niger State, teachers have used cardboard models to create 3D representations of the ruminant digestive system. These models are made from inexpensive materials and constructed by students as part of interactive learning projects. A study revealed that when students built these models themselves, they not only gained a stronger understanding of the digestive system but were also able to apply this knowledge in later assessments (Ibrahim & Musa, 2022).

Student-Centered Perspectives: The Impact of Interactive Models on Retention

When students have the chance to interact with 3D digital models or physical models, they tend to report better engagement and retention. In one recent study, students working with interactive 3D models of the ruminant digestive system mentioned how much easier it was to understand the system. One student shared, "When I saw the ruminant stomach in 3D, it was easier to understand how food moves through it. It made much more sense than just reading about it."

Teachers also observed that students who engaged with physical models were more likely to participate in classroom discussions. They could explain the functions of each stomach compartment more effectively, demonstrating a deeper understanding. Bakare & Obasi (2021)

argue that by involving students in hands-on activities, interactive models help make them active participants in their learning, which leads to better retention.

However, the effectiveness of interactive models in improving retention can vary depending on the context. For example, students in well-resourced schools may benefit from high-tech digital simulations, while those in rural areas may rely on affordable physical models. Despite these differences, both types of models have been shown to improve retention, which highlights that interactive learning is effective in different educational settings.

Potential Limitations of Interactive Models

Despite the many benefits, interactive models do have some challenges. One of the biggest barriers is cost. Digital models, in particular, require significant investments in technology—computers, software, and teacher training. In resource-limited environments, the cost of these models can be prohibitive.

Another challenge is the time required to create and implement these models. Teachers often have to design and build the physical models themselves, which can be time-consuming, especially with large classes. In overcrowded classrooms, where time is limited, this can be a real obstacle.

However, low-cost physical models made from locally sourced materials offer an alternative. Teachers can create these models, using materials like cardboard, foam, and plastic, making them affordable for schools with limited budgets (Ibrahim & Musa, 2022).

Pedagogical Frameworks Supporting Interactive Models

The success of interactive models in enhancing retention can be explained by several pedagogical theories. Cognitive Load Theory (CLT) suggests that students learn more effectively when the cognitive load is optimized. Interactive models reduce intrinsic cognitive load by simplifying complex processes, while providing a multimodal learning experience that makes retention easier (Sweller, 1988).

Another helpful framework is Constructivist Learning Theory. According to Piaget (1972) and Vygotsky (1978), active learning—where students construct their own knowledge through hands-on activities—is more effective than passive learning. By interacting with physical models, students engage in active learning, which leads to deeper understanding and better retention (Oladejo et al., 2023).

Dual Coding Theory (Paivio, 1986) also supports the use of interactive models. This theory suggests that when students process information using both visual and verbal channels, their ability to retain and apply knowledge improves. By combining interactive models with verbal explanations, educators provide students with multiple ways to encode information, which enhances long-term retention.

Long-Term Impact and Application of Interactive Models in Real-World Contexts

While interactive models are effective for short-term retention, their real value lies in helping students apply their knowledge in practical, real-world contexts. Students who engage with interactive models of the ruminant digestive system are better equipped to understand and manage livestock and apply this knowledge in agricultural careers or farming practices.

Further research is needed to examine the long-term impact of interactive models on students' ability to apply their knowledge in real-world agricultural scenarios. This could include exploring how students who were exposed to interactive models perform in agricultural careers or livestock management. Such research would provide deeper insights into the real-world relevance of these models and how they shape future professionals in agriculture.

Additionally, comparing the effectiveness of digital versus physical models would be valuable. Digital models provide immersive, animated simulations, but physical models offer hands-on engagement, which has been shown to improve memory retention. Research could help educators understand which model works best in different settings, taking into account the available resources and educational context.

Conclusion

Interactive learning models, whether digital or physical, are an invaluable tool for improving retention in agricultural science education. By allowing students to engage actively with abstract concepts, such as the ruminant digestive system, these models foster a deeper understanding and longer retention of material. Student feedback, case studies, and pedagogical theories support the effectiveness of these models in enhancing student outcomes. While challenges such as cost, time, and resource limitations remain, low-cost physical models offer a viable alternative for schools with limited resources. Moving forward, exploring the long-term impact of interactive models on real-world applications and comparing the outcomes of digital and physical models will be essential to further refine their use in agricultural science education.

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THE ROLE OF CAREER SKILLS IN FOSTERING HIGHER-ORDER THINKING AMONG PRE-SERVICE UNIVERSITY EDUCATORS: A CONTEMPORARY PERSPECTIVE

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Abstract

In contemporary teacher education, the development of higher-order thinking skills (HOTS) has become indispensable for preparing pre-service educators to meet the demands of 21st-century classrooms. This opinion paper explores how the integration of career skills such as problem-solving, collaboration, digital competence, creativity and adaptability can enhance HOTS among pre-service university educators. Drawing on recent empirical and theoretical literature, the paper argues that teacher preparation must move beyond traditional pedagogies to embrace active, reflective and technology-driven learning experiences. It highlights innovative models including flipped learning, service-learning and AI-assisted instruction as powerful tools for embedding both career and cognitive competencies. The discussion concludes that fostering HOTS through career-oriented frameworks not only enriches teacher education but also prepares graduates for complex real-world challenges. Recommendations are made for curriculum redesign, professional collaboration and policy reorientation toward skill-based higher education.

Keywords: *Higher-order thinking skills; Career skills; Pre-service university educators; Flipped learning; Service-learning; Artificial intelligence in education and Teacher education reform*

Introduction

Education in the 21st century demands a fundamental rethinking of how pre-service teachers are trained to think, teach and solve problems. The rapid evolution of technology, the changing world of work and the complex social challenges educators face require university programmes to focus not only on content mastery but also on career-relevant competencies that stimulate higher-order thinking (Zain *et al.*, 2022; Ajani, 2024). Career skills often referred to as employability or transferable skills include critical thinking, creativity, communication, collaboration, adaptability and digital literacy. These align closely with the core components of HOTS: analysis, synthesis, evaluation and innovation (Ghanizadeh *et al.*, 2020).

This paper presents a contemporary perspective on the intersection between career skills and higher-order thinking among pre-service university educators. It contends that career skills are not separate from cognitive development; rather, they serve as both means and outcomes of cultivating HOTS. The discussion synthesises recent literature and emerging practices to advocate for a more integrated teacher education model that aligns with global competency frameworks.

Conceptualizing Career Skills and Higher-Order Thinking

Higher-order thinking involves the capacity to analyse, evaluate and create skills that go beyond rote memorisation and factual recall. According to Bloom's revised taxonomy, HOTS represents the upper levels of cognitive processing essential for complex learning and problem-solving

(Tanak, 2020). For pre-service educators, developing these competencies is critical, as their teaching effectiveness depends on their ability to stimulate similar thinking in their future students. Career skills, in contrast, encompass a broader range of competencies necessary for workplace success and lifelong learning. These include communication, collaboration, leadership and digital proficiency skills that correspond directly with HOTS dimensions (Keengwe & Byamukama, 2018). When pre-service teachers engage in tasks that require creativity, reflection and innovation, they are not only building employability but also strengthening their cognitive capacities. Therefore, the synergy between career skills and HOTS should form the core of teacher education design.

Career Skills as Catalysts for Higher-Order Thinking

Problem-Solving and Reflective Practice

Problem-solving is both a career skill and a cognitive process central to HOTS. Ajani (2024) emphasises that problem-based learning (PBL) and reflective teaching tasks enhance pre-service teachers' analytical and evaluative thinking. Engaging in authentic, ill-structured problems helps teacher trainees bridge theory and practice mirroring the complexity of real classrooms. Similarly, Zhang, Tian and Lu (2025) found that integrating generative artificial intelligence (AI) into teacher preparation enhances problem-solving and metacognitive awareness by allowing learners to explore multiple solution pathways.

Collaboration and Peer Learning

Collaborative learning environments provide fertile ground for developing both interpersonal and higher-order thinking skills. Fang *et al.* (2021) demonstrated that online collaborative peer-assessment practices significantly improved pre-service teachers' digital competence and HOTS by fostering evaluative judgment and collective reflection. Group-based learning models promote the negotiation of meaning, argumentation and shared decision-making essential elements of both career adaptability and advanced cognition (Zain *et al.*, 2022).

Creativity and Innovation

Creativity is increasingly recognised as a foundational career skill linked to higher cognitive engagement. Ghanizadeh *et al.* (2020) argue that creative thinking serves as a bridge between knowledge and innovation, encouraging pre-service teachers to generate original instructional strategies and learning materials. By designing novel teaching aids, lesson plans, or digital content, pre-service educators engage in synthesis and innovation—hallmarks of HOTS.

Pedagogical Approaches that Integrate Career and Higher-Order Thinking Skills

Flipped Learning

Flipped learning has proven effective in encouraging self-directed inquiry and collaboration. Zain, Sailin and Mahmor (2022) reported that group-based flipped learning significantly promoted HOTS among pre-service teachers by encouraging pre-class preparation and in-class problem-solving discussions. The model cultivates independence, digital literacy and teamwork—skills central to both career readiness and deep learning.

Service-Learning

Saeed and Ahmed (2021) found that a service-learning approach, where teacher trainees engage with community-based educational projects, enhances HOTS by linking academic theory to social

realities. Through experiential engagement, pre-service teachers apply critical reflection, ethical reasoning and social responsibility dimensions that strengthen both professional and cognitive growth.

Technology and Artificial Intelligence Integration

The emergence of generative AI has opened new avenues for enhancing HOTS development. Zhang *et al.* (2025) demonstrated that AI-supported learning promotes problem-solving, creativity and critical evaluation among pre-service educators. When used responsibly, AI tools can model cognitive processes, simulate teaching scenarios and offer instant feedback that stimulates reflective and adaptive thinking.

Challenges in Embedding Career Skills and HOTS in Teacher Education

Despite the proven benefits, integrating career skills into HOTS-focused teacher education faces several challenges. First, rigid curricula often emphasise theoretical content over practical application (Taştı & Yıldırım, 2022). Many university programmes remain exam-oriented, which discourages creativity and risk-taking. Second, limited access to digital tools and insufficient staff training impede technology-enhanced pedagogies that support HOTS (Fang *et al.*, 2021). Finally, cultural and institutional resistance to change especially in developing contexts can hinder collaborative and experiential learning models (Saeed & Ahmed, 2021).

Overcoming these barriers requires rethinking teacher preparation frameworks. Educators must be trained as facilitators who model critical inquiry and innovation. Institutional policies should promote interdisciplinary projects, peer learning and digital integration that align with global education goals.

Policy and Curriculum Implications

The integration of career skills into HOTS development carries profound implications for educational policy and curriculum design. Firstly, curriculum developers should embed competency-based learning outcomes that measure not only academic achievement but also transferable skills such as communication, problem-solving and collaboration. Secondly, assessment practices should evolve from standardised testing to performance-based evaluations that capture authentic learning (Tanak, 2020).

Moreover, teacher education institutions should partner with industry, schools and technology providers to design **real-world learning experiences** that connect theory to practice. Such collaboration strengthens employability and prepares pre-service educators for lifelong professional adaptability. Finally, continuous professional development (CPD) initiatives must be institutionalised to ensure that educators remain abreast of emerging pedagogical trends, including AI literacy and global competencies (Keengwe & Byamukama, 2018).

Future Directions and Research Needs

While existing literature demonstrates the positive relationship between career skills and HOTS, more empirical work is needed to understand how these interactions evolve over time. Longitudinal studies could explore how pre-service teachers transfer higher-order and career skills into classroom practice post-graduation. Furthermore, cross-cultural research could identify contextual differences in how teacher training institutions implement HOTS-based curricula (Taştı

& Yıldırım, 2022). The growing influence of AI-driven learning also warrants critical investigation into ethical considerations, cognitive load and digital equity (Zhang *et al.*, 2025).

Conclusion

The cultivation of higher-order thinking among pre-service educators is inseparable from the development of career skills. Together, they form the backbone of teacher education for the 21st century enabling future teachers to think critically, act creatively and adapt to a rapidly evolving world. As the reviewed studies illustrate, innovative pedagogies such as flipped learning, service-learning, collaborative peer assessment and AI-enhanced instruction provide powerful avenues for integrating these competencies. To actualise this vision, higher education institutions must embrace flexible curricula, evidence-based pedagogy and forward-thinking policy frameworks that recognise the interdependence between cognitive and professional growth. In doing so, they will not only prepare effective educators but also nurture a generation capable of transforming learning for the future.

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CHALLENGES OF USING INFORMATION RESOURCES FOR RESEARCH ACTIVITIES BY LIBRARY AND INFORMATION SCIENCE POSTGRADUATE STUDENTS IN FEDERAL UNIVERSITIES IN NORTH-CENTRAL NIGERIA

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Abstract

The study investigated challenges of using information resources for research activities by library and information science postgraduate students in federal universities in North-central, Nigeria. This research determined the extent of use of information resources for research activities, challenges of using information resources for research activities and find out the types of information resources use for research activities by library and information science postgraduate students in federal universities in North-central, Nigeria. The study adopted descriptive survey research design and content analysis. The population of the study comprised of 265 postgraduates' students of Library and Information Science in federal universities in north-central, Nigeria by subjecting the target population of 850 to Krejcie and Morgan table. Questionnaire was adopted and designed as a survey instrument for data collection. Out of 265 copies of questionnaire distributed, 213(80%) copies were properly filled, returned and used for the analysis. Data were analyzed using frequency counts, percentages and mean. The findings of the study revealed that: extent of use of information resources by postgraduates' students is high with a mean score of ($\bar{x}=3.14$) and low with a mean score of ($\bar{x}=2.63$). inadequate funding ($\bar{x}=2.90$), poor infrastructure ($\bar{x}=2.76$) and poor catalogueing and classification ($\bar{x}=2.75$) are the major challenges of using information resources by postgraduates' students of Library and Information Science in North-central, Nigeria. To effectively prevent future problems the study therefore, recommended that federal universities in North-central, Nigeria should organize user workshop at the beginning of every semester or sessions for students to enable them to make effective use of information resources, provide skilled manpower to facilitate easy access and use of information resources in both print and electronic format and formulate sound collection development policy, particularly, for online information resources such as e-journals, e-reference, e-books, online databases, e-theses/dissertations, audio visual material etcetera.

Keywords: Information Resources, Research Activities, Challenges, Use and North-central Nigeria.

Introduction

University library is a library attached to a university to provide access to information resources in order to support teaching, learning and research activities in the university. It is the nerve center that supports academic programmes in the university environment through the provision of information resources and services. Information resources are vital tools in every university library. Information resources refer to data, materials, and tools used to support knowledge, learning, research, decision making, and communication. The success of any library depends on its resources and the utilization of its resources (Nwosu and Opara 2019). These resources enable learners to engage in in-depth research, stay updated with current trends and broaden their

understanding of various topics within the profession. Information resources provided by university libraries play a vital role in enhancing educational and professional programmes. These resources not only contribute to individual learning and professional development but also facilitate research, collaboration and preservation of knowledge within the discipline (Kobieliev *et al.*, 2022).

University libraries often offer workshops, training sessions and support services to enhance information literacy skills, ensuring that individuals can make use of the most available resources. Tang & Tseng (2013) examined the use of digital databases in university libraries to enhance students' research skills and information literacy. Libraries, both physical and digital are instrumental in facilitating the academic journey of postgraduate students. Beyond being repositories of information, modern libraries serve as collaborative spaces, providing access to a wide range of academic materials and resources. Research activities encompass systematic investigations aimed at generating new knowledge or applying existing knowledge in innovative ways. These activities include defining and redefining problems, formulating hypotheses, collecting and analysing data, making deductions, and reaching conclusions. Research activities in a university system are the systematic efforts undertaken to investigate study develop new knowledge, often to discoveries, innovations and contributions to a field of study. Access to a wide range of digital databases positively influenced students' ability to conduct comprehensive and critical research, resulting in higher-quality academic work. Vasylenko *et al.* (2022) conducted a study focused on the use of online journals in university libraries. The research indicated that the availability of online journals improved students' access to current and relevant research, enabling them to keep abreast of emerging trends and developments in the field. A contemporary extensive university library boasts an array of educational resources, from textbooks to scholarly publications and reference materials. This priceless collection empowers students and professionals with access to the latest and most comprehensive information on various topics within their field. Journals, available in electronic format, offer the most current research and scholarly articles. By staying up to date with the latest findings and exploring diverse perspectives, individuals can contribute to advancing knowledge in their specialization while also honing their analytical and critical thinking skills.

Regular utilization of information resources reflects their importance in supporting academic coursework, research projects and professional development activities. The high usage rate of information resources provided by university libraries showcases their importance in enhancing educational and professional programmes (Atuase & Maluleka, 2023). The availability of a diverse collection of books, journals, databases, digital collections and archival materials supports learning, research and professional development, enabling students and professionals to stay informed, contribute to knowledge and excel in their respective endeavours. students and professionals have access to various types of information resources such as textbooks, reference books, research monographs and scholarly publications, enabling them to explore various aspects of the discipline of their research (Pashkevich *et al.*, 2020).

Access to a diverse range of resources ensures that students and professionals have the necessary tools to explore, analyse and apply information in their studies and professional practice. Constant engagement with information resources promotes lifelong learning and fosters a culture of intellectual curiosity within the field. These programmes should equip them with the necessary

skills, knowledge and competencies to navigate the complexities of today's information landscape. Ntui et al. (2015) noted that academic libraries provide vital resources and services in the teaching-learning encounter; these resources are important for the preparation of lesson plan by teachers and for educational advancement in order to achieve the set instructional objectives; library resources include; textbooks, journal, indexes, abstracts, newspapers, magazines, pamphlets, reports, bulletins, project booklets, dictionaries, encyclopedias, etc. Apart from the print academic library resources, another valuable resources student can lay hands on in the library are non-print resources. According to Anand (2014) non-print resources are resources in electronic format that is accessible electronically examples include; e-journals, e-books, online databases, pdf documents, webpages etc.

Prangya and Rabindra (2013) found that lack of training; poor infrastructure and high cost of usage are the obstacles to proper and full utilization of electronic resources. The major problems of using e-resources are lack of subscription in particular fields of study; lack of user orientation or training, low bandwidth, lack of printing facilities; terminals, trained staff, unavailability of sufficient e-resources, doubts in permanency, high purchase price and lack of legal provision. Obuh (2009) conducted a study in Nigeria, where it was observed that there is a general endorsement by respondent of issues like a large mass of irrelevant information; therefore, the need to filter the results from search were some of the basic problems encountered while using e-resources.

Other problem observed in the study were download delay, failure to find information, lack of search skills, high cost of access, power outages, unavailability of some websites, inaccessibility of some websites and difficulties in navigating through e-resources. The other factors include short period of material loan, inconvenience of the opening hours in the library and the number of books loaned out at a time is inadequate for their research purpose. These among others were factors militating against their utilization of information resources for research and also lack of trained Library staff; poor cataloguing and classification method constitute problems to student utilization of Library services.

Statement of the Research Problem

The diverse and comprehensive information accessible through libraries, both in traditional print formats and modern electronic resources, serves as a reservoir from which students draw the essential elements of their academic pursuits. Whether through textbooks, academic journals, or online databases, students in higher institutions rely on these resources for their research activities. Despite advancements in library services and digital resources, the level of awareness, accessibility and competence in using these resources remains inconsistent. This has led to varying degrees of research productivity among postgraduate students. Therefore, understanding the relationship between information resources and research activities is crucial to enhancing postgraduate research outcomes. Anyira and Imade (2020) asserted that lack of enough qualified Librarians to provide, process and make available Library information resources and services, infrastructural facilities, electricity, inadequate funding of the libraries, lack of adequate modern information technologies to acquire, process and access current information nationally and internationally and available information resources in their areas of research are mostly outdated are major factors militating against utilization of information resources for research activities. It is on this basis that this study tends to investigate challenges and use of information resources for research research activities of

post graduate students in library and information science department in federal university libraries in North-central, Nigeria.

Objectives of the Study

The aim of the study is to investigate the challenges of using information resources for research activities by library and information science postgraduate students in federal universities in North-central, Nigeria.

1. Determine the extent of use of information resources for research activities by library and information science postgraduate students in federal universities in North-central, Nigeria.
2. Ascertain the challenges of using information resources for research activities by postgraduate students in federal universities in North-central, Nigeria.
3. Find out the types of information resources use for research activities by library and information science postgraduate students in federal universities in North-central, Nigeria.

Research Questions

The following research questions guided the study.

1. What is the extent of use of electronic information resources for research activities by library and information science postgraduate students in federal universities in North-central, Nigeria.
2. What are the challenges of using information resources for research activities by postgraduate students in federal universities in North-central, Nigeria.
3. What are the types of information resources use for research activities by postgraduate students in federal universities in North-central, Nigeria.

Research Methodology

The study adopted descriptive survey research design. The population of the study comprised of 850 drawn from postgraduate students offering Library and Information Science in federal university in North-central, Nigeria namely: Federal University of Technology, Minna, University of Abuja, University of Ilorin and University of Jos. The sample size of the population is 265. This sample size was obtained by subjecting the target population of 850 to Krejcie and Morgan 1970 recommended table for determining sample size of a population. A questionnaire was used as instrument for data collection. A total of two hundred and sixty-five (265) copies of questionnaire were administered to Library and Information Science postgraduate students in federal universities in North-central, Nigeria. A total of two hundred and thirteen (213) copies of questionnaire, representing 80% response rate were properly filled and returned for analysis.

Table 1.1 showed the response rate based on the copies of questionnaire administered, returned and their percentage rates in the study areas.

S/N	Name of Federal Universities	No. of Administered Questionnaire	Number of Returned Questionnaire	Percentages
1	Federal University of Technology, Minna	60	46	76
2	University of Jos, Plateau State	82	69	84
3	University of Abuja	32	24	75

4	University of Ilorin, Kwara State	91	74	81
	Total	265	213	80

Table 1.1 revealed that 60 copies of questionnaire were administered to library and information science postgraduate students in Federal University of Technology, Minna, out of which 46 copies representing 76% of the valid questionnaire were returned, 82 copies of the questionnaire were administered to library and information science postgraduate students in University of Jos, Plateau State, 69 copies representing 84% of the valid questionnaire were returned, 32 copies of questionnaire were administered to library and information science postgraduate students in University of Abuja, 24 copies representing 75% of the valid questionnaire were returned and 91 copies of questionnaire were administered to library and information science postgraduate students in University of Ilorin, Kwara State, 74 copies representing 81% were returned.

Answer to Research Questions

1. What is the extent of use of information resources for research activities by library and information science postgraduate students in federal universities in North-central, Nigeria.

S/N	Statements	VHE	HE	LE	VLE	N	FX	$\bar{X}$	Decision
1	Conduct research	76	69	40	28	213	619	2.90	High
2	Professional development	91	74	35	13	213	669	3.14	High
3	Promote lifelong learning	66	70	55	22	213	606	2.84	High
4	Improve information literacy skill	45	80	53	35	213	561	2.63	Low
5	Preservation of knowledge	89	74	35	15	213	663	3.11	High
6	Collaborating with peers and faculty members	68	43	77	25	213	580	2.72	Low
	Weighted Mean							2.81	

Key: Very High Extent (VHE), High Extent (HE), Low Extent (LE), Very Low Extent (VLE)

Table 2 showed the extent of use of information resources for research activities by library and information science postgraduate students. Out of the six items listed, four items listed produced high mean scores which were above the weighted mean of 2.81. These items include item 2: Professional development ($\bar{x}$ =3.14), item 5: Preservation of knowledge ($\bar{x}$ =3.11), item 1: Conduct research ($\bar{x}$ =2.90) and item 3: Promote life long learning ($\bar{x}$ =2.84). On the other hand, two items produced low mean scores which were below the weighted mean of 2.81. These items include item 6: collaborating with peers and faculty members ($\bar{x}$ =2.73) and item 4: Improve information literacy ($\bar{x}$ =2.63). From the analysis, the study revealed that item 2, 5, 1 and 3 were rated high extent by the respondents, while item 6 and 4 were rated low extent by the respondents.

The result showed that the extent of use of information resources for research activities by postgraduates students of Library and Information Science students federal universities in North-central, Nigeria is high.

2. What are the challenges of using information resources for research activities by postgraduate students in federal universities in North-central, Nigeria

S/N	Statements	SA	A	DA	SD	N	FX	$\bar{X}$	Decision
1	Poor infrastructure	57	82	41	33	213	589	2.76	Agreed
2	Inadequate funding	69	78	43	23	213	619	2.90	Agreed
3	Poor catalogueing and classification method	56	81	43	33	213	586	2.75	Agreed
4	Large mass irrelevant information	60	53	59	30	213	602	2.56	Disagreed
5	Lack of trained staff and user orientation	49	68	59	37	213	555	2.60	Disagreed
6	Lack of research skills	62	55	60	36	213	569	2.67	Disagreed
Weighted Mean								2.75	

Table 3 showed the challenges of use of information resources by library and information science postgraduate students. Out of the six items listed, four items listed produced high mean scores which were above the weighted mean of 2.75. These items include item 2: Inadequate funding ($x=2.90$), item 1: Poor infrastructure ($x=2.76$) and item 3: Poor catalogueing and classification method ($x=2.75$). On the other hand, three items produced low mean scores which were below the weighted mean of 2.75. These items include item 6: Lack of research skills ($x=2.67$), item 5: lack of trained staff and user orientation ($x=2.60$) and item 4: large mass irrelevant materials ($x=2.51$). From the analysis, the study revealed that item 2, 1 and 3 were rated high by the respondents, while item 6, 5 and 4 were rated low by the respondents.

The result showed that the challenges of use of information resources by library and information science postgraduate students in federal universities in North-central, Nigeria is moderate.

4. What are the types of information resources use for research activities by postgraduate students of Library and Information Science in federal universities in North-central, Nigeria.

S/N	Statements	SA	A	D	SD	N	FX	$\bar{X}$	Decision
1	Textbooks	64	54	30	29	213	507	2.38	Low
2	Journals	57	77	43	36	213	581	2.72	High
3	Online databases	58	90	39	26	213	606	2.84	High
4	Theses and Dissertations	43	62	73	35	213	539	2.53	Low
5	Magazines and Newspaper	63	86	38	26	213	526	2.46	Low
6	E-journal	70	68	43	32	213	602	2.82	High
7	E-books	50	88	35	40	213	574	2.69	High
8	Pamphlets	60	70	45	38	213	578	2.17	Low
9	Audio visual materials e.g CD, DVD, streaming videos	40	50	65	58	213	498	2.33	Low
10	Online resources and web site	89	72	23	45	213	663	3.11	High
Weighted Mean								2.60	

Table 4 showed the influence of use of artificial intelligence on academic activities by library and information science postgraduate students. Out of the nine items listed, five items listed produced high mean scores which were above the weighted mean of 2.60. These items include item 10: online resources and website ($x=3.11$), item 3: Online databases ($x=2.84$), item 6: E-Journal ($x=2.82$), item 2: Journal ($x=2.72$) and item 7: E-books ($x=2.69$). On the other hand, five items produced low mean scores which were below the weighted mean of 2.60. These items include item 4: theses and dissertations ($x=2.53$), item 5: Magazines and newspapers ($x=2.46$), item 1: Textbooks ($x=2.38$), Item 9: Audio visual materials e.g streaming video, CD, DVD ($x=2.33$), item and 8: Pamphlets ($x=2.17$). From the analysis, the study revealed that item 1,3,6,2 and 7 were rated high by the respondents, while item 4, 5, 9 and 8 were rated low by -the respondents. The result showed that types of information resources used for research activities by library and information science postgraduate students in federal universities in North-central, Nigeria is moderate.

Discussion of Findings

The result from research question one revealed that the extent of use of information resources for research activities is high. This is in line with findings of Abubakar (2017) who asserted that utilisation of information resources is the extent to which the resources of the library are actually used for teaching, learning and research. Therefore, information resources utilisation is the actual putting into appropriate use of acquired information and may differ from person to person, one discipline to another, one faculty to another as well as from one corporate organisation to the other according to their information needs and other socio-economic imperatives.

The survey indicates that a good number of respondents ranked books, journals, e-books and e-journals very higher. Government publications, atlas, maps and posters for instance are the type of library information resources ranked very lower

In this context therefore, training and re-training are necessary requirement for ensuring effective and efficient utilization of information resources. In addition, the digital information resources, funding, staff productivity and capabilities through education and training opportunities in line with the objectives of the library should be improved.

The result showed that the challenges of using information resources for research activities by library and information science postgraduate students is moderate. This corroborate with the findings of Osinulu (2020) who asserted that inadequate funds, poor internet connectivity, lack of skills/knowledge, limited subscribed titles, inadequate power supply, inadequate infrastructure and lack of staff orientation and training are challenges of using information resources for research activities by postgraduate students in constraints to effective use of electronic information resources by postgraduate students in the library studied.

The result showed that the respondents agreed with the types of information resources use by library and information science postgraduate students which journals, textbooks, online databases, audio visual materials, newspapers and magazines etcetera. This is in line with the findings of Ankrah and Atuase (2018) who revealed that the various types and forms of information resources in academic libraries are; e-databases, e-journals, e-data archives, e-manuscript, maps, books, magazines, e-thesis, WWW, e-newspapers, e-research reports, and bibliographic databases.

Conclusion

This study has explored the degree at which specific information resources for research activities are provided to postgraduate students in library and information science in Nigeria. The study has also found that both print and electronic information resources play essential roles in the academic pursuits of the postgraduate students of library and information science under study. The respondents are postgraduate students of Library and Information Science in federal universities in North-central, Nigeria. The study indicated that they have inadequate funding and shortage of trained library staff to provide orientation for research activities. The respondents face some problems in using the library resources for research activities. So, they need some training to be able to use the resources, particularly the electronic resources appropriately. The study has attempted to understand the extent of use of information resources by the postgraduate students of library and information science in federal universities. The study suggests that federal university libraries in North-central, Nigeria should maintain the needed based print and electronic resources. Well qualified and adequate staff should be recruited in the federal university Libraries in North-central, Nigeria.

Recommendations

Based on the findings of the study, the following recommendations were made:

1. Federal universities in north-central, Nigeria should organize user workshop at the beginning of every semester or sessions for students to enable them to make effective use of information resources. The workshop should focus more on the use of academic database and other electronic information resources with major emphasis on online databases, CD-ROM and Internet facility to enable the students broaden their search and narrow their search results.
2. Federal universities in north-central, Nigeria should provide skilled manpower to facilitate easy access and use of information resources in both print and electronic format.
3. Federal university libraries in north-central, Nigeria should Formulate sound collection development policy, particularly, for online information resources. The preferred information resources such as subject journals, e-journals, e-reference books, online databases, theses/dissertations, audio visual material, bibliographies and reviews need to be updated regularly.

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EFFECTS OF COMPUTER ASSISTED INSTRUCTION WITH ANIMATION AND CONCEPT MAPPING INSTRUCTIONS ON BIOLOGY STUDENTS' RETENTION DURING THE COVID-19 PANDEMIC IN NIGER STATE, NIGERIA

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Abstract

The integration of digital technologies into classroom instruction has become essential for improving students' learning outcomes, particularly in technology-related subjects such as Computer Studies. However, persistent low performance and poor retention among secondary school students suggest limitations in the continued use of conventional teaching methods. This study investigated the effect of the Wakelet learning platform on students' academic achievement, retention, and learning satisfaction in Computer Studies among Senior Secondary School students in Edati Local Government Area, Niger State, Nigeria. A quasi-experimental research design involving experimental and control groups was adopted. Students in the experimental group were taught using the Wakelet platform, while those in the control group received conventional instruction. Data were collected using the Computer Studies Achievement Test (CSAT), Computer Studies Retention Test (CSRT), and Computer Studies Students' Satisfaction Questionnaire (CSSSQ). Descriptive statistics and independent samples t-test were used for data analysis at the 0.05 level of significance. The findings indicated that students exposed to Wakelet-based instruction demonstrated improved academic achievement, better retention of learned concepts, and higher learning satisfaction compared to those taught using conventional methods. Gender differences were also examined to determine variations in learning outcomes. The study concludes that the Wakelet platform is an effective digital instructional tool for enhancing learning outcomes in Computer Studies. It is therefore recommended that teachers and curriculum planners integrate Wakelet and similar digital platforms into secondary school instruction to promote interactive and learner-centered teaching practices.

Keywords: Academic Achievement, Computer Studies, Digital Learning Platform, Gender Differences, Learning Satisfaction, Retention, Secondary School Students and Wakelet Platform

Introduction

The 2020 to date teaching and learning has been frustrated by the current State of the COVID-19 pandemic all over the world. The financial status of the developed nations and the underdeveloped nations have been paralysed by the dreaded viral disease, thus affecting all the spheres of human endeavours, most importantly the educational sector. The advanced nations have been able to, on a lighter note, adopt several technology-mediated instructional strategies such as the use of virtual classroom, Zoom, Skype and other social media platforms. The current status of affairs in the developing nations has been the use of ancient media of communication, such as the Radio and Television at primary to secondary school levels, and sparsely the use of Instagram at tertiary levels. Technology-mediated instructional platforms that were widely used by educators, researchers and scholars before the advent of COVID-19 viral infection have been Computer-Assisted Instruction (CAI); Computer-Assisted Instruction (CAI); Computer Manage Instruction

(CMI); Computer-Based Instruction (CBI), among others. The above-mentioned technology-mediated instructions flourished significantly before the COVID-19 pandemic, which brought a series of protocols such as social distancing, thus making learning so difficult and leading to the closure of some colleges completely. This current trend, therefore, calls for the revisiting of these media sources of instruction characterised by individualised instruction to salvage the problem of large class sizes, which are not favourable for instruction during this hard time of COVID-19.

Computer-assisted instruction is a technology-mediated instruction, which could be used in an individualised format or collaboratively Alabi (2018). The COVID-19 pandemic protocol could best be adhered to when this technology is designed to be used by learners individually, based on adequate spacing and distancing. Similarly, Mudasini and Adedeji (2010) emphasise the utilisation of Computer-Assisted Instruction in the enhancement of students' performance in Biology. Anderson *et al* (2021) also revealed a significant improvement in Biology achievement when a computer-aided instructional package on Biology was used in teaching genetic concepts. Computer Concept Mapping Instruction has been widely used, especially in third-world countries. Concept maps are diagrams that show the relationships between concepts. They are graphical representations that are used to organise and structure knowledge (Okebukola, 2019). Usually, they are made up of two key components: "concept" and "linking words" or "phrase"; the linking words are utilised in joining two or more concepts, thereby generating propositions. Mayer (2018) opine that concept maps provide a graphic representation of an individual's scheme of knowledge or conceptual meaning of a particular topic.

Retention has been seen as the repetition of performance of a given task or learnt behaviour earlier acquired by a learner. It may be regarded as the preservative factor of the mind (Gana, 2013). Research studies have shown that CAI enhance the students' retention of concepts learnt (Olatoye *et al* 2021). COVID-19 is a viral disease that emanated from China in Wuhan, China in 2020. The COVID-19 pandemic has paralysed virtually all human activities on the globe. The viral disease originated from China in 2019, particularly in the WUHAN province (WHO, 2020). The Pandemic has led to the disruption of various social, cultural, educational and other entrepreneurial activities in the world at large. However, many strategies have been adopted to curb the transmission of the normal class settings. COVID-19-associated closure of institutions has affected about 1540 million students across 191 nations, and 32 million students in Nigerian educational institutions are to equip their citizens with the best knowledge, skills and attitude to live as an acceptable member of a given society. It is sad to note that the achievement of these noble objectives has been threatened by the COVID-19 pandemic. The revisiting theme among scholars, educators and researchers, among others, has been the gender imbalance in academic achievement and retention. Olatoye and Afuwape (2018), Wushishi *et al* (2013), and Ibrahim (2016) in their study revealed that gender disparity exists among students in various subjects. However, some established a significant retention ability among male and female students, some revealed a non-significant relationship, such as Umoke and Nwafor (2018), among others. In relation to this study, the researcher investigated the effects of Computer-Assisted Instruction with Animation and Concept Mapping Instruction on Biology students' retention during the COVID-19 pandemic in Niger state, Nigeria.

Statement of the problem

The insurance of the COVID-19 pandemic in the world has disrupted the academic calendar, closure of schools, conferences, teaching, examination extension, and the time of graduation,

among others. Before the outbreak of COVID-19, disease research was conducted involving a large number of students in the research environment and positive results were yielded with no protocol of distancing and other related protocols. This study, therefore, applied the strict COVID-19 protocol compliance in its quest to generate verifiable data that would be used in conducting research using technology-mediated instructional packages. The technique that may be more favourable during this period of the COVID-19 pandemic may be the use of CAIP and CMIP, characterised by individualised learning that would match with current COVID-19 protocols. Therefore, the study investigated the effects of computer instruction (with animation) and Concept Mapping Instruction on Biology students' retention during the COVID-19 pandemic in Niger state, Nigeria.

Null Hypotheses

The null hypotheses formulated were;

HO₁: There is no significant difference between retention scores of students taught Biology using CAI, CMI and those in the conventional lecture method environment.

HO₂: There is no significant difference between the retention scores of male and female taught Biology with CAI

HO₃: There is no significant difference between the scores of male and female students taught Biology with CMI.

Methodology

The study's design was an experimental design; specifically, the non-randomised, non-equivalent pretest-posttest control group design was adopted because the school authorities did not allow for random selection of students. In this case, intact classes were used for the study. The population of the study comprised male and female students in the co-educational schools. Target population for the study was Senior Secondary two (SSII) students; the choice of the level was based on the topic treated which fell in their scheme of work. The population consists of homogeneous characteristics such as school type, environmental features, staff and location.

The sample size consisted of 367 students from the intact classes used. A simple random sampling technique was employed to select the schools and then an arm of each class from the various classes, ranging from A to E arms. The data collection instrument was developed by the researcher based on the six levels of Bloom's cognitive domain. However, the items were arranged hierarchically, from lower to higher levels, with most items focusing on knowledge, comprehension, and application, and very few on analysis, synthesis, and creativity (i.e., Test Blue Print). Thirty (30) questions were developed, each with five answer options, only one of which was correct, plus distractors. The items were subjected to item analysis to ensure their validity. The test was labelled as the Biology Retention Test (BRT) and underwent validation by a panel of experts from the Test and Measurement section of the Niger State Ministry of Education (NME). Validation focused on face validity, which involved the sequential arrangement of the items, and content validity, which concerned the accuracy and relevance of the subject matter covered in the study. To assess the items' reliability, the split-half method was used, involving administering the test to students from a school within the population that was not among the sampled schools for the study.

The scores obtained were later split into levels, and the KR-21 formula was used to analyse the data, and $r=0.74$ was obtained, indicating that the items were reliable. Before the administration of the instrument, the Covid-19 protocol team investigated the learning environments to ensure that the seating arrangement were done based on the social distancing criteria when this was done and satisfied by the team, the researcher trained the research assistants and the students on the guides of manipulation the computers and navigation among others for a period of one week under strict compliance to Covid-19 protocols. For the avoidance of doubt, three (3) members of the Covid-19 team were always present at the venue of the administration of the treatment up to the end of the research study. The second week was used for the administration pretest of the treatment to the three groups: experimental group I (CAIP), experimental group II (CMIP) and control group (CLM), for two weeks respectively.

The CAIP and CMIP were self-tutoring packages specifically individualised in nature and provided with a mechanism for assessing and navigating students to the next question if a trial is done and a wrong answer is taken. After the second trial, the program automatically navigates the students to the next question, even if the wrong answer was picked. Before the second trial, the program took the learner to the portion not understood, which led to the choice of wrong answer. The whole process lasted for two weeks, including the control group, there after the third week was left without any administration of treatment or test (posttest). In the fourth week, the Biology Retention Test (BRT) was administered to the three groups; the one-week gap was created purposefully to determine the level of retention of the concepts learnt. Pretest questions were reshuffled before it was used for the retention test to create an impression that they were different from the ones administered during the pretest. The data collected were sorted, coded and subjected to analysis. The pretest scores were used as a covariate for the retention scores. Mean and standard deviation were used to analyse the pretest scores, while Analysis of Covariance (ANCONA) was used to test the hypotheses at an alpha level of 0.05.

Results and Discussion

H0₁: there is no significant difference between retention scores of students taught Biology using CAI, CMI and those taught using conventional method

To answer this, ANCOVA analysis was used.

Table 1: ANCOVA Analysis of the scores of CAI, CMI and CLM groups in Retention

Dependent Variable	Sum of Square	df	Mean Squared	F	Sig	Partial Squared
Corrected model	729.667	2	364.662	16.332	.000	-.320
Interapt	3710.427	1	3710.427	166.201	.000	.766
Strategy	379.205	1	379.295	13.210	.001	-.121
Error	1339.701	1	1339.701	.000		-.222
Total	53555.001	60	22.309			
Corrected Total	2069.260	63				

R. Squared =-.352(adjusted R squared=.332)

Table 1 shows there is significant difference between the strategies CAI, CMI and CLM, therefore, hypothesis was rejected and further analysis conducted to determine statistically the difference, using a post hoc analysis of Schiff posthoc.

Table 2: Post-hoc Analysis of the CAI, CMI and CLM Groups

Strategy	CAI	CMI	CLM
CAI	-	4.251	5.621
CMI	-4.202	-	5.23
CLM	-5.621	-5.23	-

Table shows that the CAI group did better than the CMI group and CMI group did better than the CLM I in that order. Therefore. CAI was most effective, followed by CMI and lastly by CLM group respectively

H0₂: there is no significant difference in the retention scores of males and female taught with CAI.

To answer this, independent sample t-test was used

Table 3: Independent t-test Analysis of Male and Female in CAI Group

Group	NO	Df	Mean	p-val	sig
Male	40	60	33.45	0.222	0.21
Female	22		32.35		

S=significant at 0.05 level ($p < 0.05$)

Table 3 shows that there is no significant difference between the male and female exposed to CAI, the male has a mean score of 33.45 and female 32.35, $p\text{-val}=0.222$ and significant at 0.05 level of significance. Hence hypothesis two was rejected, that is significant difference between the two groups

H0₃: there is no significant difference between the retention scores of male and female exposed to CMI

To answer this, independent t-test was used.

Table 4. Independent t-test Analysis of male and female exposed to CMI

Group	NO	Df	Mean	p-val	sig
Male	40	60	40.21	0.425	0.524
Female	22		30.33		

NS= Not significant at 0.05

Table 4 shows that there is no significant difference between the male and female exposed to CMI instruction. The p -val=0.425 and significant at 0.524 at $p>0.05$. Hence, hypothesis 3 was retained.

Discussion of Results

The findings of the results are in agreement with the findings of other researchers such as; Alabi (2018), Anderson and Krathwohl (2021), Mayer (2018) and Ibrahim (2016) who establish in their studies that CAI and CMI administered on students improved their learning outcomes. Similarly, Umoke and Nwafor (2014), Olatoye and Afuwape (2018) also corroborated the findings of the study by indicating that CAI and CMI are gender friendly.

Conclusion

It has been established that CAI and CMI are more versatile instructional strategies than CLM. Also, the study revealed that, there is no disparity in learning outcomes of male and female exposed to CAI, but differences existed between male and female exposed to CMI.

Recommendations

1. It is recommended that computer Assisted Instruction and concepts mapping instruction should be utilized by Biology tutors in teaching processes
2. Re-training of tutors on the need to use CAI and CMI in teaching Biology.

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INTEGRATING ARTIFICIAL INTELLIGENCE AND AUGMENTED REALITY FOR STEM-ORIENTED HOME ECONOMICS PRE-SERVICE TEACHER EDUCATION

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Abstract

Teacher education in Nigeria is at a pivotal stage where digital transformation is necessary to meet the demands of a STEM-driven global economy. Home Economics an applied, skill-based discipline remains central to national development but is constrained by inadequate facilities, high material costs, and traditional teacher-centred approaches. This review explores the integration of Artificial Intelligence (AI) and Augmented Reality (AR) to enhance learning outcomes in STEM-oriented Home Economics pre-service teacher education. It synthesizes theoretical perspectives and empirical findings on AI-AR synergy in promoting adaptive, immersive, and collaborative learning environments. The paper argues that combining AI's data-driven intelligence with AR's visualization potential can transform Home Economics pedagogy by fostering engagement, creativity, and self-efficacy. Within the STEM framework, AI-enhanced AR supports experiential learning, interdisciplinary thinking, and digital competence, thereby contributing to a skilled and innovative teaching workforce. Policy, curriculum, and infrastructural recommendations are advanced to guide sustainable adoption of emerging technologies in teacher preparation programs across Nigerian Colleges of Education.

Keywords: Artificial Intelligence, Augmented Reality, STEM Education, Home Economics, Pre-Service Teachers, Educational Technology, Nigeria

Introduction

The global educational landscape is undergoing a profound transformation driven by the rapid advancement of digital technologies and artificial intelligence. In the 21st century, teachers are expected not only to be knowledge transmitters but also facilitators of critical thinking, creativity, and innovation through the effective use of technology (Holmes *et al.*, 2022; UNESCO, 2023). The demand for technologically fluent educators capable of integrating digital tools into instruction is increasingly recognized as a prerequisite for achieving quality education and sustainable development. This transformation is particularly vital for developing nations like Nigeria, where education remains a cornerstone for national growth and workforce competitiveness (Federal Ministry of Education [FME], 2023).

Teacher education in Nigeria, especially in vocational and technical disciplines such as Home Economics, faces persistent challenges that undermine skill acquisition and practical competence. Despite the subject's potential to promote self-reliance, entrepreneurship, and socio-economic empowerment, many Colleges of Education still rely on traditional, teacher-centered pedagogies that limit student engagement and creativity (Ogunleye, Adebayo, & Aliyu, 2021; Okoye & Adegboye, 2022). These pedagogies often neglect experiential and problem-based learning approaches that are essential for preparing pre-service teachers to function effectively in modern

classrooms. Furthermore, chronic issues such as inadequate instructional materials, overcrowded workshops, and insufficient funding for practical sessions continue to weaken the quality of teacher preparation (Nwosu & Iwuanyanwu, 2020).

The Fourth Industrial Revolution has introduced technologies such as Artificial Intelligence (AI), Augmented Reality (AR), Virtual Reality (VR), and Machine Learning (ML), all of which are redefining pedagogical models and learning experiences across disciplines (Luckin *et al.*, 2022). Among these, AI and AR stand out for their potential to enhance cognitive engagement, visualization, and adaptive instruction. AI supports teachers and learners through intelligent tutoring systems, predictive analytics, and personalized learning recommendations (Zawacki-Richter *et al.*, 2019; Spector, 2021). It enables data-driven insights that can identify learning gaps, monitor progress, and optimize teaching strategies (Kerr & Kong, 2023). On the other hand, AR enriches classroom experiences by overlaying digital content onto the physical environment, providing immersive and interactive simulations that bridge the gap between abstract theory and practical application (Di Serio, Ibáñez, & Kloos, 2013; Li *et al.*, 2025).

Integrating AI and AR into Home Economics teacher education within a STEM-oriented framework offers a powerful avenue for transformation. A STEM-based perspective emphasizes inquiry, experimentation, and interdisciplinary problem-solving, all of which are fundamental for equipping pre-service teachers with 21st-century competencies (Bybee, 2013; Adeoye & Musa, 2021). When AI and AR are synergized, they can create intelligent immersive learning environments (IILEs) where learners receive real-time feedback, manipulate virtual models, and collaborate on complex design or production tasks (Bower *et al.*, 2023). Such integration not only enhances knowledge retention and practical skill development but also builds digital confidence and pedagogical innovation among pre-service teachers (Abich *et al.*, 2021).

Moreover, AI-AR-enabled pedagogy aligns with Nigeria's current educational reform agenda, which seeks to leverage digital tools to improve teacher quality, inclusion, and employability outcomes (FME, 2023; National Universities Commission [NUC], 2022). Within this vision, Home Economics can be repositioned as a STEM-aligned discipline that fosters innovation, gender equity, and sustainable livelihoods. Consequently, this paper critically examines the conceptual, theoretical, and empirical foundations of integrating AI and AR in Home Economics pre-service teacher education. It further discusses their implications for pedagogical practice, institutional readiness, and policy development in Nigeria's Colleges of Education.

STEM Education as a Foundation for Innovation

STEM education an integrated approach to teaching Science, Technology, Engineering, and Mathematics is widely recognized as the foundation for innovation and sustainable national development (Bybee, 2013; Marginson *et al.*, 2019). It promotes inquiry, critical thinking, creativity, and collaboration skills essential for economic growth and competitiveness in the 21st century. Within the Nigerian context, STEM has become a crucial policy focus for revitalizing teacher education and bridging the gap between academic learning and industrial needs (Federal Ministry of Education [FME], 2021).

Integrating Home Economics into STEM education extends beyond traditional domestic skill acquisition. It situates Home Economics within a scientific and technological framework that

fosters problem-solving, innovation, and entrepreneurship (Okoye & Adegboye, 2022). For instance, teaching nutrition through STEM allows learners to explore biochemical processes in food preparation, use digital measuring tools for precision, and apply engineering principles to sustainable housing and textile design. This interdisciplinary fusion promotes not only conceptual understanding but also practical competence in addressing real-world challenges such as food security, health, and sustainable living (Yildirim & Türk, 2023).

Embedding Home Economics in STEM education thus enhances vocational relevance and technological adaptability, positioning pre-service teachers to cultivate a skilled and innovative workforce. As Oladipo and Adeoye (2022) observe, effective STEM integration in teacher education requires a paradigm shift from rote knowledge transmission to active, technology-mediated learning that develops both technical and humanistic capacities.

Theoretical Underpinnings

The conceptual framework guiding this review is rooted in constructivist and experiential learning theories, which emphasize that knowledge is actively constructed through engagement, reflection, and collaboration (Piaget, 1970; Vygotsky, 1978; Kolb, 1984). Constructivism suggests that learning occurs when individuals interact with their environment and generate personal meaning from experiences. Vygotsky's (1978) social constructivism extends this by underscoring the importance of social interaction, dialogue, and scaffolding in facilitating deeper learning.

Kolb's (1984) experiential learning cycle comprising concrete experience, reflective observation, abstract conceptualization, and active experimentation provides a model for iterative learning through practice and reflection. In teacher education, this theory underscores the importance of connecting pedagogical theory with classroom practice.

AI and AR technologies concretize these theoretical perspectives by creating interactive and adaptive learning environments. For instance, AI-driven analytics can provide individualized feedback and tailor learning paths to each student's progress (Zawacki-Richter et al., 2019), while AR simulations allow learners to manipulate virtual materials and observe cause-and-effect relationships in real time (Di Serio, Ibáñez, & Kloos, 2013; Li *et al.*, 2025). Such immersive experiences foster cognitive engagement, conceptual understanding, and skill mastery key outcomes aligned with constructivist and experiential learning paradigms.

Integrating AI and AR within Educational Technology

Educational technology refers to the systematic application of technological tools, theories, and processes to enhance learning and improve instructional outcomes (Mishra & Koehler, 2006). Within this domain, the convergence of Artificial Intelligence (AI) and Augmented Reality (AR) represents a transformative shift in the design and delivery of instruction (Chen et al., 2022).

AI offers computational capabilities such as adaptive learning, intelligent tutoring, and predictive analytics, which allow instructors to identify learners' strengths and weaknesses and provide targeted interventions (Holmes *et al.*, 2021). Meanwhile, AR introduces immersive, spatially aware experiences that blend real and virtual environments, enhancing visualization and engagement (Ibáñez & Delgado-Kloos, 2018). When these technologies are combined, they enable

real-time assessment, dynamic feedback, and contextualized exploration, transforming the learning process from passive reception to active discovery (Abich et al., 2021).

For example, an AI-powered AR module in Home Economics could allow pre-service teachers to virtually design kitchen layouts, simulate nutrition experiments, or explore textile structures while receiving real-time guidance from intelligent systems. Such integration supports personalized learning pathways, promotes experiential engagement, and aligns with the global movement toward Industry 4.0 education (Luckin *et al.*, 2022).

Ultimately, AI–AR fusion in educational technology shifts instruction from teacher-centered delivery to learner-centered, data-informed pedagogy, enabling pre-service teachers to acquire both technological competence and critical thinking skills essential for STEM-based Home Economics instruction (Umar & Olatunde, 2023).

Artificial Intelligence in STEM Teacher Education

Artificial Intelligence (AI) refers to computer systems designed to perform tasks that typically require human cognition, including reasoning, pattern recognition, natural language processing, and decision-making (Russell & Norvig, 2020). Within the educational context, AI represents a transformative force capable of reshaping pedagogy, assessment, and learner engagement. It leverages algorithms and data analytics to enhance personalized learning, automate administrative operations, and generate predictive insights on student performance and learning trajectories (Holmes *et al.*, 2022).

The integration of AI in STEM teacher education has gained global traction as institutions strive to prepare future educators who are technologically literate, data-driven, and capable of designing adaptive learning experiences (Luckin *et al.*, 2022). For pre-service teachers, particularly in vocational disciplines such as Home Economics, AI serves not merely as an instructional tool but as a pedagogical partner enhancing reflection, creativity, and teaching efficiency. AI-enabled learning environments provide opportunities to model differentiated instruction, foster problem-based learning, and integrate real-world data for practical application (Zawacki-Richter *et al.*, 2019; Li & Zhao, 2024).

In Nigeria, where teacher education faces challenges of resource scarcity and inadequate digital infrastructure, AI offers scalable solutions to bridge gaps in instructional delivery and assessment (Oladipo & Adeoye, 2022). Through intelligent platforms, pre-service teachers can access adaptive simulations, receive real-time formative feedback, and engage in professional learning communities supported by AI-driven analytics. Thus, AI is pivotal to the ongoing transformation of teacher education into a **STEM-oriented, innovation-driven ecosystem**.

Applications in Teacher Preparation

AI-driven tools have become integral to teacher preparation, providing dynamic and evidence-based approaches to professional learning. **Intelligent Tutoring Systems (ITS)**, for example, adapt content based on learners' progress, ensuring mastery of pedagogical concepts through scaffolding and feedback (VanLehn, 2019). Similarly, **Learning Analytics Dashboards (LADs)** synthesize complex data into visual insights that enable pre-service teachers to reflect on

instructional effectiveness, track competency growth, and identify students at risk of underachievement (Siemens & Long, 2011; Zawacki-Richter et al., 2019).

Moreover, **AI-powered chatbots** and virtual teaching assistants support asynchronous interaction, guiding learners through problem-solving processes and providing instant feedback (Chen et al., 2022). In Home Economics education, AI applications can simulate food science experiments, model textile processes, or evaluate hygiene practices through virtual environments making learning both accessible and interactive (Ogunleye et al., 2021). These affordances embody **constructivist and experiential principles**, as learners actively engage in exploration and reflection rather than passive content consumption.

AI further supports **competency-based teacher education** by enabling individualized professional development. Adaptive platforms analyze each trainee's performance across teaching dimensions such as lesson planning, classroom management, and instructional design and provide tailored recommendations for improvement (Holmes et al., 2021). Through such diagnostic systems, pre-service teachers develop metacognitive awareness and pedagogical agility key competencies in STEM-oriented Home Economics instruction.

Benefits and Limitations

AI's potential benefits in STEM teacher education are multifaceted. It enables personalized learning, allowing instruction to be adjusted according to learners' pace, interests, and cognitive profiles (Kerr & Kong, 2023). The technology enhances inclusivity by accommodating diverse learning needs, thereby supporting students with varying levels of digital literacy or special educational needs (UNESCO, 2023). Additionally, AI automates routine administrative tasks such as grading and attendance tracking freeing educators to focus on higher-order pedagogical functions like mentoring and design thinking (Holmes et al., 2022).

However, alongside these advantages come ethical, logistical, and pedagogical challenges. Data privacy concerns persist, particularly in contexts with weak digital governance frameworks. Sensitive learner data collected by AI systems may be vulnerable to misuse or breaches (Williamson & Eynon, 2020). Algorithmic bias also poses risks, as machine learning models trained on biased data can reinforce existing inequalities in education (Baker & Smith, 2019). Additionally, the financial cost of procuring AI infrastructure and training personnel remains a major constraint for Nigerian institutions (Oladipo & Adeoye, 2022).

Balancing automation with human agency is critical to maintaining pedagogical integrity in teacher education. As Kerr and Kong (2023) note, effective AI integration should complement not replace the teacher's professional judgment, empathy, and contextual awareness. In vocational education, especially in Home Economics, emotional intelligence, cultural sensitivity, and social interaction are indispensable. Thus, sustainable AI adoption requires ethical frameworks, continuous professional development, and inclusive digital policies to ensure equity, transparency, and accountability.

Augmented Reality in Vocational and Technical Education

Augmented Reality (AR) represents an emerging technological innovation that overlays digital information such as 3D models, images, animations, or contextual data onto the real-world

environment through mobile devices, head-mounted displays, or wearable glasses (Azuma, 1997; Di Serio *et al.*, 2013). Unlike Virtual Reality (VR), which immerses learners in a fully simulated environment, AR enriches the physical world with virtual elements, fostering interactive and spatially meaningful learning experiences. The use of AR in education bridges the gap between theoretical abstraction and practical engagement by enabling learners to visualize invisible concepts, manipulate digital objects, and receive real-time multimodal feedback (Yuen *et al.*, 2021).

In vocational and technical education (VTE), where hands-on experiences and material resources are essential, AR has emerged as a transformative instructional medium (Abich *et al.*, 2021). By providing simulations of complex or costly processes, AR enhances accessibility, safety, and cost efficiency while promoting active learning and collaboration. As institutions strive to align VTE programs with STEM and digital literacy goals, AR provides an adaptable framework for cultivating creativity, innovation, and technical competence among pre-service teachers.

Evidence from Prior Studies

Empirical evidence consistently supports the pedagogical value of AR across multiple disciplines. Di Serio, Ibáñez, and Kloos (2013) demonstrated that AR significantly enhances student motivation, retention, and conceptual understanding compared to traditional teaching methods. Similarly, a meta-analysis by Li *et al.* (2025) found that AR applications produced a medium-to-large effect size on academic achievement across STEM disciplines, particularly in subjects requiring spatial reasoning such as engineering, biology, and architecture.

In vocational education, AR technologies have been applied to simulate authentic environments that would otherwise be difficult to reproduce due to material constraints or safety concerns. For instance, García *et al.* (2022) reported that AR-based simulations in automotive training allowed students to visualize mechanical systems and troubleshoot engine faults virtually, thereby reducing equipment wear and resource costs. In fashion design and textile education, students using AR tools demonstrated improved precision and creativity in pattern drafting and garment construction tasks (Zhou *et al.*, 2021).

Research also highlights AR's positive influence on learner engagement and collaboration. According to Bower *et al.* (2020), AR's interactive and experiential features encourage teamwork, dialogue, and shared exploration, aligning with constructivist and social learning theories. These findings validate AR as a cost-effective instructional innovation capable of enhancing motivation, retention, and skill mastery in VTE contexts.

Furthermore, in developing nations, AR provides an equitable learning alternative by compensating for limited laboratory resources and material shortages (Abich *et al.*, 2021). Through mobile-based AR platforms, students in resource-constrained environments can access virtual laboratories that replicate real-world conditions, thereby expanding opportunities for quality learning without heavy infrastructure investment. This aligns with the United Nations' Sustainable Development Goal 4, which advocates inclusive and equitable quality education through technology-enabled learning (UNESCO, 2023).

AR for Home Economics Instruction

Home Economics education, as a branch of vocational studies, emphasizes the acquisition of practical skills in food preparation, clothing construction, interior design, and family resource management. These domains inherently require visualization, manipulation, and sensory engagement, which traditional lecture-based teaching often fails to provide (Ogunleye *et al.*, 2021). Integrating AR into Home Economics instruction can transform abstract concepts into tangible, interactive experiences that support experiential learning and skill retention.

For example, in clothing and textile education, AR applications can display 3D models of garments, illustrate step-by-step pattern drafting, or simulate fabric behavior under different conditions. Such visual tools enhance learners' understanding of proportion, texture, and structure while reducing the need for costly materials (Weng *et al.*, 2022). In food and nutrition education, AR can provide interactive overlays that demonstrate ingredient combinations, nutritional information, and safe cooking procedures, allowing students to experiment virtually before performing real-life cooking tasks (Garzón *et al.*, 2020). Similarly, in interior design, AR enables pre-service teachers to visualize room layouts and test aesthetic arrangements in a digitally augmented environment, reinforcing design thinking and spatial reasoning (Rau *et al.*, 2022).

AR's integration into Home Economics aligns strongly with STEM-oriented learning principles, as it incorporates science (food chemistry, textile physics), technology (digital modeling), engineering (pattern drafting and structural design), and mathematics (measurement and proportion). When coupled with Artificial Intelligence, AR can further personalize instruction analyzing user interaction data to adapt simulations based on learner proficiency and preferences (Li & Zhao, 2024).

Moreover, AR enhances inclusivity and learner autonomy by allowing self-paced, exploratory learning. Through mobile AR applications, pre-service teachers can engage in guided practice beyond classroom boundaries, increasing accessibility and continuity of learning (Yuen *et al.*, 2021). This approach democratizes skill acquisition and prepares future Home Economics teachers to adopt innovative pedagogies aligned with 21st-century teaching competencies.

The AI–AR Synergy: A Transformative Approach

The convergence of Artificial Intelligence (AI) and Augmented Reality (AR) represents one of the most transformative frontiers in educational innovation. While AI contributes data-driven personalization, predictive analytics, and adaptive scaffolding, AR enriches the sensory and experiential dimensions of learning by providing interactive 3D visualizations and simulated contexts (Bower *et al.*, 2023; Chen *et al.*, 2022). Within teacher education particularly in practice-based disciplines such as Home Economics this synergy fosters experiential, reflective, and context-aware learning experiences that transcend traditional pedagogical limitations. The AI–AR ecosystem functions as a responsive instructional framework that observes learner behavior, interprets engagement patterns, and dynamically modifies content to support individual learning trajectories (Davenport *et al.*, 2021).

Integrating AI and AR within vocational teacher education thus represents a paradigm shift from static curriculum delivery to adaptive, participatory, and cognitively enriched instruction. For instance, an AI-powered AR platform can guide pre-service Home Economics teachers through a

virtual kitchen setup, identify errors in food handling, and provide real-time corrective feedback. Such applications cultivate procedural fluency, safety awareness, and confidence prior to real-life practice. This hybridization of intelligent analytics and immersive visualization not only enhances skill acquisition but also reinforces reflective practice, a core competency in professional teacher training (Kamarainen et al., 2022).

Collaborative Learning Integration

The integration of AI and AR also strengthens collaborative learning, an essential component of STEM-oriented pedagogy. Through AI-supported AR environments, learners can co-create virtual artifacts, share real-time annotations, and receive adaptive guidance that promotes shared cognition and teamwork (Azar *et al.*, 2021; Lee & Chen, 2023). When applied to Home Economics teacher preparation, such collaboration might involve group-based interior design projects or meal-planning simulations, where AI agents monitor task progression and provide formative feedback.

Furthermore, embedding AI–AR tools within structured cooperative strategies such as Think-Pair-Share, Peer-Led Guided Learning, or Reciprocal Peer Tutoring supports interactive problem-solving and social negotiation of meaning (Johnson & Johnson, 2019). AI algorithms can assess group dynamics, identify participation gaps, and suggest equitable task redistribution, thereby ensuring inclusivity and engagement (Kukulska-Hulme *et al.*, 2022). Research indicates that AI-mediated collaboration enhances pre-service teachers' communication, metacognitive awareness, and professional self-efficacy more effectively than traditional group work (Azar et al., 2021; Bower *et al.*, 2023).

Cognitive and Affective Benefits

The cognitive and affective impacts of AI–AR learning environments are profound. By engaging multiple sensory modalities visual, auditory, and kinesthetic AI–AR systems enhance information processing and long-term memory retention (Wu et al., 2020). For Home Economics education, where skill-based mastery is essential, this multimodal engagement enables learners to understand complex spatial and procedural concepts, such as fabric cutting, meal portioning, or room layout design, with greater clarity and accuracy (Cheng & Tsai, 2022).

Affective benefits are equally critical. AI–AR simulations allow pre-service teachers to rehearse instructional procedures and technical skills in low-risk virtual spaces, reducing performance anxiety and promoting confidence (Mouza *et al.*, 2023). Through real-time feedback and empathetic AI tutors, learners develop resilience and reflective judgment, which are crucial in navigating unpredictable classroom scenarios. Moreover, the gamified nature of AI–AR learning fosters intrinsic motivation, sustaining engagement across challenging or repetitive tasks (Li et al., 2025). Collectively, these benefits position AI–AR integration as a transformative strategy for cultivating competent, confident, and innovative Home Economics educators aligned with 21st-century STEM competencies.

Challenges and Ethical Considerations

Despite the transformative potential of Artificial Intelligence (AI) and Augmented Reality (AR) in STEM-oriented Home Economics teacher education, their adoption within Nigerian institutions faces significant infrastructural, financial, ethical, and attitudinal barriers. Understanding these

challenges is essential to developing contextually appropriate policies and sustainable implementation strategies.

Infrastructure Limitations

The successful deployment of AI–AR systems depends on stable internet connectivity, adequate bandwidth, and reliable power supply factors that remain problematic in many developing contexts (Oluwatobi & Oladipo, 2022). In Nigeria, inconsistent electricity and limited broadband coverage impede continuous access to cloud-based learning platforms and virtual laboratories. AR applications, in particular, require high processing power and real-time rendering capabilities that may be unavailable on standard institutional devices (Aremu et al., 2023). These infrastructural constraints risk widening the digital divide between technologically advanced and resource-limited teacher education institutions.

Financial Constraints

The high cost of hardware such as AR-enabled devices, smart glasses, and AI-supported servers presents another significant obstacle (Tondeur et al., 2021). Many faculties of education operate on limited budgets that prioritize basic teaching materials over emerging technologies. Moreover, recurring expenses software licensing, network upgrades, and system maintenance add to financial pressure, particularly where government funding is insufficient. According to Aremu and Hassan (2023), the cost of integrating immersive technologies in Nigerian universities can exceed annual ICT budgets by up to 40%. Consequently, without external partnerships or open-source alternatives, many teacher education programs may remain technologically stagnant.

Ethical Concerns

AI–AR integration introduces complex ethical challenges regarding data privacy, algorithmic transparency, and digital surveillance. AI-driven systems collect extensive learner data to personalize instruction, but weak institutional data governance frameworks in many developing countries increase the risk of breaches or misuse (Holmes *et al.*, 2022). Similarly, opaque algorithms may produce biased or discriminatory outcomes, undermining fairness and inclusivity in assessment (Kerr & Kong, 2023). In vocational training contexts such as Home Economics, where gender stereotypes already influence subject perception, unchecked AI algorithms may reinforce social bias rather than mitigate it (Williamson & Eynon, 2020). Thus, there is a pressing need for clear ethical guidelines that ensure accountability, transparency, and equitable representation in AI-based educational systems.

Resistance to Change and Capacity Gaps

Human factors often constitute the most persistent barrier to technological adoption. Teachers' resistance to AI–AR integration is frequently rooted in limited digital literacy, fear of job displacement, and uncertainty about pedagogical relevance (Onwuagboke & Singh, 2021). In Nigeria, pre-service teacher training programs still emphasize traditional pedagogy, leaving many educators underprepared for emerging digital paradigms. Without systematic professional development, teachers may perceive AI and AR as complex or unnecessary innovations. Research underscores that sustained motivation, administrative support, and hands-on exposure are critical for overcoming resistance and promoting technology confidence among educators (Alamri & Tyler, 2022).

Addressing the Challenges

Mitigating these challenges requires multi-stakeholder collaboration, involving universities, government agencies, private technology providers, and donor organizations. Strategic investments in infrastructure and teacher capacity-building programs are essential to achieving sustainable technology integration (UNESCO, 2023). Open-source AI-AR tools such as TensorFlow, Unity AR Foundation, and Google's ARCore can provide cost-effective entry points for institutions with limited resources. Moreover, developing locally relevant content and ethical standards grounded in African educational realities will ensure contextual appropriateness and cultural sensitivity (Adeoye et al., 2022). Ultimately, a phased, participatory approach emphasizing inclusivity, transparency, and sustainability will support equitable integration of AI-AR technologies in Home Economics teacher education.

Conclusion and Recommendations

The integration of Artificial Intelligence and Augmented Reality into STEM-oriented Home Economics teacher education offers a transformative pathway toward modernizing instructional delivery and learning outcomes. Artificial Intelligence provides personalized learning experiences, adaptive feedback, and performance analytics, while Augmented Reality enhances visualization and practical engagement through immersive simulations. Together, these technologies bridge the gap between theory and practice, helping pre-service teachers develop creativity, confidence, and digital competence. Embedding AI and AR within the STEM framework prepares future Home Economics educators for the demands of a technology-driven society. It promotes innovation, collaboration, and problem-solving skills that are critical for building a skilled and sustainable workforce. However, effective adoption requires adequate infrastructure, continuous lecturer training, supportive institutional policies, and ethical safeguards. When properly implemented, AI-AR integration can redefine teacher education by equipping pre-service teachers with 21st-century competencies and the ability to foster interactive, inclusive, and technology-enhanced learning environments. This approach holds great potential to strengthen vocational education and contribute significantly to national development goals.

Recommendations

1. **Curriculum Integration:** Embed AI-AR learning modules into Home Economics programs at Colleges of Education.
2. **Lecturer Development:** Provide continuous professional training in emerging educational technologies.
3. **Infrastructure Investment:** Expand digital facilities and access to AR-enabled devices.
4. **Policy Reform:** Establish national guidelines supporting AI-AR inclusion in STEM teacher education.
5. **Research Collaboration:** Encourage interdisciplinary studies to assess long-term effects on workforce readiness and innovation.

By leveraging AI-AR synergy within a STEM framework, Nigeria can cultivate digitally competent, innovative educators capable of driving sustainable socio-economic transformation.

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EFFECT OF HANDS-ON-EXPERIMENTS ON ACHIEVEMENT AND RETENTION AMONG SECONDARY SCHOOL CHEMISTRY STUDNETS IN MINNA METROPOLIS

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Abstract

*Chemistry, often regarded as the central science, plays a vital role in connecting physical, life, and applied sciences, and is fundamental for students aspiring to pursue careers in Science, Technology, Engineering, and Mathematics (STEM). Despite its significance, chemistry is frequently perceived as a difficult subject due to its abstract concepts and complex problem-solving demands, resulting in low achievement and retention rates among secondary school students. This paper investigates the effects of hands-on experiment approaches on students' achievement and retention in chemistry, comparing them with conventional lecture-based methods. Grounded in social cognitive theory, constructivism, and the **expectancy-value theory**, the study emphasizes that hands-on experiments—where students actively engage in laboratory activities—enhance conceptual understanding, motivation, and long-term knowledge retention by linking theory to real-world applications. Empirical studies reveal that students exposed to hands-on learning demonstrate improved academic performance, deeper conceptual comprehension, and greater self-efficacy compared to those taught through traditional methods. Moreover, the interactive nature of laboratory-based learning fosters curiosity, critical thinking, and sustained interest in STEM careers. However, the adoption of hands-on experiments faces challenges such as limited resources, safety concerns, and inadequate teacher training. The paper highlights the need for educational policies and institutional support to address these barriers and promote active learning environments. Additionally, it underscores the importance of inclusive pedagogies that ensure equitable access and gender-sensitive approaches in chemistry education.*

Key words: *Effects, Hands-On-Experiment, Achievement, Retention.*

Introduction

Chemistry is a science subject often termed the central science. This is because it bridges physical sciences with life sciences and as well as with other applied sciences such as medicine and engineering. In secondary education, chemistry is essential for students aiming at careers in Science, Technology, Engineering and Mathematics (STEM) fields. Despite its critical role, chemistry is frequently perceived as a difficult subject, characterized by abstract concepts, complex reactions, and mathematical applications. This perception has led to poor academic performance, low retention rates, and a general lack of interest among students (Broderick, 2023). This paper highlights the effects of hands-on experiment approach, which involves students actively engaging in practical activities to explore and understand chemical concepts. Hands-on experiments provide concrete experiences that link theoretical knowledge to real-world applications, thereby enhancing understanding and retention. This approach allows students to see the relevance of what they are learning by directly observing chemical reactions, manipulating materials, and collecting data. Through these activities, students are not only able to grasp abstract

concepts more effectively but also develop essential scientific skills, such as observation, measurement and data analysis (Pols *et al.*, 2021).

Hands-on experiments in chemistry education

Hands-on experiments play a pivotal role in chemistry education by actively involving students in the learning process and enabling them to directly interact with the material they are studying. This instructional approach is grounded in experiential learning theories, which posit that knowledge is best acquired through active engagement and personal experience.

Research consistently supports the efficacy of hands-on experiments in enhancing students' understanding of complex chemical concepts and processes. For instance, a study by Hofstein, A., & Hugerat, M (2021) highlighted that student who participate in hands-on laboratory activities exhibit a deeper comprehension of abstract ideas, such as molecular structures and chemical reactions, compared to those who only receive traditional lecture-based instruction. This hands-on engagement helps demystify challenging concepts by allowing students to observe phenomena firsthand, manipulate materials, and draw connections between theoretical knowledge and real-world applications.

McCanc *et al.* (2023) posit that students involved in regular laboratory activities report higher levels of engagement and interest in the subject. This increased interest is crucial for fostering a positive attitude towards science, which can influence students' educational trajectories and career choices in STEM fields. The interactive nature of hands-on experiments captures students' curiosity and encourages them to ask questions and seek out answers, thus fostering a more inquisitive and motivated approach to learning.

Benefit of hands-on experiments

The benefits of hands-on experiments extend beyond academic achievement and cognitive skills. These activities can also enhance students' confidence in their scientific abilities. Engaging in experiments where they successfully test hypotheses and observe expected outcomes can reinforce students' belief in their capabilities as scientists. This confidence can translate into a more proactive and engaged approach to learning, where students are more willing to tackle challenging problems and persist in the face of difficulties. A study by Chengere *et al.*, (2025) found that students who participate in hands-on experiments exhibit greater self-efficacy and are more likely to pursue further studies and careers in chemistry and related fields.

Despite the clear benefits of hands-on experiments, their implementation in secondary school chemistry education is often limited by several challenges. These include resource constraints, safety concerns, and the need for extensive teacher training to effectively facilitate laboratory activities. Addressing these challenges requires a concerted effort from educators, administrators, and policymakers. Providing adequate funding for laboratory equipment and materials, ensuring proper safety protocols, and investing in professional development for teachers are essential steps to make hands-on experiments a standard part of chemistry education. Additionally, integrating hands-on activities with digital tools and simulations can enhance accessibility and complement traditional laboratory experiences, providing a more comprehensive and flexible approach to learning chemistry.

Conventional teaching methods as a Baseline for Instructional Comparison

Conventional teaching methods, primarily characterized by lecture-based instruction and rote memorization, have long been the cornerstone of chemistry education. These methods typically involve the teacher delivering content to students in a didactic manner, with students expected to passively absorb information and reproduce it during assessments. While this approach has been effective in disseminating large amounts of information in a structured manner, it has several inherent limitations that hinder its effectiveness in fostering deep learning and engagement. Recent studies have increasingly highlighted these drawbacks, particularly in the context of modern educational needs that emphasize critical thinking, problem-solving, and the application of knowledge. According to a study by Margulieux *et al.* (2021), students taught through conventional lectures often struggle with conceptual understanding and are less able to apply their knowledge to novel problems. This is because the passive nature of lectures does not encourage students to engage in the higher-order cognitive processes necessary for deep learning, such as analysis, synthesis, and evaluation.

Conventional teaching methods also fall short in developing critical thinking and problem-solving skills, which are essential for success in both academic and professional settings. Because traditional lectures do not typically involve interactive or hands-on components, students have limited opportunities to practice these skills in a meaningful context. Instead, they may become proficient at rote memorization and regurgitation of information without developing the ability to think critically about the material or apply it to real-world situations. A meta-analysis by Tatal and Yazar (2022) highlighted that active learning techniques, which require students to engage with the material through discussion, experimentation, and problem-solving, are far more effective at developing these higher-order skills. This research underscores the need for instructional strategies that move beyond conventional methods to actively involve students in the learning process.

However, conventional teaching methods continue to serve as a baseline for comparison in educational research. Their widespread use and historical dominance in education provide a clear point of reference for evaluating the effectiveness of alternative instructional strategies. By comparing the outcomes of students taught through conventional methods with those engaged in more interactive and student-centered approaches, researchers can gain valuable insights into the relative strengths and weaknesses of different pedagogical techniques. This comparative approach is crucial for understanding how best to improve educational practices and outcomes.

Academic Achievement in Chemistry

Academic achievement in chemistry is a crucial metric for evaluating the effectiveness of different instructional strategies. It encompasses not only students' performance on standardized tests and assessments but also their ability to apply chemical knowledge to solve problems and think critically about scientific concepts. Research has consistently shown that conventional lecture-based methods, while effective for disseminating information, often fall short in fostering the deep understanding and critical thinking skills necessary for high academic achievement in chemistry. For instance, Burns *et al.* (2023) conducted a meta-analysis of 225 studies and found that active learning strategies significantly improve students' performance in STEM subjects, including chemistry, compared to conventional lecturing. This finding underscores the importance of instructional methods that engage students actively and encourage them to participate in the learning process.

Hands-on experiments similarly enhance academic achievement by providing students with direct, experiential learning opportunities. These activities allow students to observe chemical reactions, manipulate variables, and see the immediate consequences of their actions, which help solidify their understanding of abstract concepts. According to Chengere et al., (2025), students who engage in regular laboratory activities demonstrate improved academic performance in chemistry. The researchers found that these students not only performed better on tests and exams but also showed greater ability to apply their knowledge in new and varied contexts. This hands-on approach promotes active learning and critical thinking, which are essential for mastering chemistry. Additionally, the impact of this instructional strategy on academic achievement is not limited to cognitive gains; it also influences students' attitudes and self-efficacy in chemistry. Positive attitudes towards the subject and confidence in one's abilities are critical for sustained academic success.

Concept of Retention in Chemistry Education

Retention of chemistry knowledge over time is a critical outcome for evaluating the effectiveness of educational strategies. The ability to retain and apply knowledge long after instruction has ended is a key indicator of deep learning and meaningful educational experiences. Conventional lecture-based teaching methods often fall short in promoting long-term retention because they typically emphasize passive learning and rote memorization, which do not effectively engage students in the deeper cognitive processes necessary for durable learning. Research has shown that students taught through conventional methods tend to forget much of what they have learned shortly after exams (Burns *et al.*, 2023). This is particularly problematic in subjects like chemistry, where understanding foundational concepts is essential for progressing to more advanced topics.

The benefit of hands-on experiment for knowledge retention is also supported by the principles of cognitive psychology. Active engagement in learning tasks enhances the encoding of information into long-term memory. According to the research of Tatal and Yazar (2022), active learning strategies, such as those employed in hands-on experiment, lead to stronger connections between new information and existing knowledge. This process, known as elaborative encoding, makes it easier for students to retrieve information when needed. Additionally, these instructional methods often incorporate spaced repetition and iterative feedback, which are proven techniques for improving memory retention.

Furthermore, the ability to transfer knowledge to new and varied contexts is a critical component of retention. Students who understand chemical principles at a deep level are more likely to successfully apply their knowledge in different scenarios, whether in advanced courses, real-world applications, or interdisciplinary contexts. Chengere *et al.*, (2025) emphasize that hands-on experiments equip students with problem-solving skills and adaptive expertise that go beyond mere memorization. This capacity for transfer is crucial for scientific literacy and the practical application of chemistry in everyday life and future careers. Despite these advantages, implementing hands-on experiment requires significant resources, including well-equipped laboratories and adequately trained teachers. Schools must invest in the necessary infrastructure and professional development to support these instructional strategies. Benjamin (2024) highlights the importance of providing ongoing support for teachers to effectively integrate active learning methods into their curriculum. This includes access to high-quality instructional materials,

opportunities for collaborative planning, and professional learning communities that foster continuous improvement.

Implications for practice and policy in the adoption of hands-on experiments

The findings of this study hold significant implications for both educational practice and policy, particularly in the realm of secondary school chemistry education. One key implication is the importance of promoting active learning strategies, such as hands-on experiments, in chemistry classrooms. This instructional approach has been shown to enhance students' academic achievement and knowledge retention in the subject. Educators can integrate hands-on experiments into their curriculum by providing opportunities for students to engage in laboratory activities, demonstrations, and practical applications of chemical concepts.

Furthermore, addressing gender-related disparities in educational outcomes requires a multifaceted approach that encompasses both policy and practice. Policymakers can play a crucial role in promoting gender equity in education by implementing policies that support the recruitment, retention, and professional development of female educators in STEM fields. Research has shown that having female role models and mentors can positively impact female students' interest and participation in STEM subjects (González-Pérez *et al.*, 2020). Additionally, policymakers can allocate resources to support the implementation of inclusive instructional practices that address the diverse needs and experiences of all students, regardless of gender or other social identities. This may include providing funding for professional development programs, curriculum materials, and instructional resources that promote equitable access and opportunities in chemistry education. By prioritizing gender equity in education policy, policymakers can create a more inclusive and supportive learning environment that empowers all students to succeed in chemistry and pursue STEM-related careers.

Moreover, educators can play a critical role in addressing gender-related disparities in educational outcomes by adopting inclusive and culturally responsive pedagogies that recognize and celebrate students' diverse identities and experiences. This includes incorporating diverse perspectives and examples into the curriculum, challenging stereotypes and biases, and creating inclusive learning environments where all students feel valued and respected. Additionally, educators can work to promote a growth mindset among students, encouraging them to believe in their ability to succeed in STEM subjects regardless of their gender or background (Yeager *et al.*, 2022). By fostering a culture of inclusivity and empowerment in the classroom, educators can help to mitigate the impact of gender-related barriers and create opportunities for all students to thrive in chemistry education.

Theoretical Framework

In constructing a robust theoretical framework for investigating the effects of hands-on experiments on achievement and retention among secondary school chemistry students, several existing theories can provide valuable insights. These theories offer frameworks for understanding the complex interplay between instructional methods, student learning outcomes, and contextual factors. Three theoretical perspectives that are particularly relevant to this study are social cognitive theory, constructivism, and the expectancy-value theory.

Social cognitive theory

Social cognitive theory, proposed by Albert Bandura, provides a comprehensive framework for understanding the complex interplay between cognitive, behavioural, and environmental factors in shaping human behaviour (Bandura, 1986). In the context of education, social cognitive theory offers valuable insights into how students' beliefs, behaviours, and learning outcomes are influenced by their interactions with their environment, social influences, and their own cognitive processes. This theory is particularly relevant to the study of instructional methods in chemistry education, as it helps elucidate how students' self-efficacy beliefs and observational learning experiences impact their engagement, motivation, and achievement in the subject.

Constructivism

Constructivism, a foundational theory in education, posits that learners actively construct knowledge through their interactions with the environment, social interactions, and prior experiences (DeVries, 2000). In the context of this study, constructivism provides a theoretical framework for understanding how students engage with and make sense of chemistry concepts through hands-on experiments and inquiry-based learning activities. By actively participating in these activities, students have the opportunity to explore chemical phenomena, manipulate materials, and collaborate with peers, which promotes deep conceptual understanding and critical thinking skills. Moreover, constructivist theory emphasizes the importance of metacognitive awareness, whereby students reflect on their learning process, monitor their understanding, and make connections between theoretical concepts and real-world applications. By applying constructivist principles, this study can investigate how hands-on and inquiry-based instructional strategies facilitate knowledge construction and conceptual development in chemistry education.

Expectancy-value Theory

Expectancy-value theory, proposed by Jacquelynne Eccles and Allan Wigfield, offers valuable insights into the motivational processes that influence students' engagement, effort, and achievement in education (Eccles and Wigfield, 2002). According to expectancy-value theory, individuals' motivation and achievement-related behaviours are influenced by two key factors: expectancy for success and the perceived value of the task or subject. Expectancy refers to individuals' beliefs about their ability to succeed in a particular task, while value refers to the perceived importance, interest, or relevance of the task or subject to the individual. In the context of chemistry education, expectancy-value theory provides a theoretical framework for understanding how students' beliefs about their ability to succeed in chemistry (expectancy) and their perceptions of the value of chemistry (value) influence their motivation, interest, and engagement in the subject.

Conclusion

This paper reaffirms that hands-on experiments represent a pedagogical innovation capable of transforming chemistry education from passive knowledge transmission to active knowledge creation. Their systematic integration into the curriculum not only enhances achievement and retention but also nurtures scientifically literate, confident, and motivated learners—an outcome indispensable for advancing national development through STEM education.

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A REVIEW ON THE IMPACTS OF ARTIFICIAL INTELLIGENCE INTEGRATION ON PROBLEM SOLVING SKILLS AMONG STUDENTS IN NIGERIA LEARNING INSTITUTIONS

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Abstract

Artificial Intelligence is fast becoming the norm of academic societies across the globe recording tremendous integration and impacts. Because of its efficacy and relevance to the current educational systems, most importantly, the students' problem-solving skills which is one of the most important skills needed in the 21st century. AI becomes widespread in the world and all hands are on the desk to prove its relevance and efficacy to humanity. This paper discussed some research evidences that were able to discover some impacts of AI on students problem-solving skills among students in Nigerian learning institutions. From the empirical evidences, it is apparent that AI alleviates academic burdens, facilitate deeper understanding of complex subjects, and enhance essential cognitive skills enhancing their analytical and evaluative abilities and problem-solving skills. It further highlighted some barriers of effective integration in to academics to include levels of digital literacy, and cultural attitudes towards technology and negative perception which can influence the perceived usage and effectiveness of AI. The paper also discovered that there is fear of students' off-loading the cognitive capabilities by AI which was also debunked by some studies. The authors concluded that Ai is but a safe and tool for the development of 21st century skills and effective teaching and learning among tertiary institutions in Nigeria.

Keywords: Artificial intelligence, problem-solving skills, perceived usage, cognitive off-loading

Introduction

In recent decades, artificial intelligence (AI) has transitioned from a theoretical concept to a transformative force across various sectors, including education. Broadly defined as the capability of machines to imitate intelligent human behaviour, A cognitive off-loading encompasses systems that can learn, reason, and self-correct (Kaplan and Haenlein, 2019). In educational contexts, this includes AI-powered tools like intelligent tutoring systems, adaptive learning platforms, and generative AI models that provide personalized instruction, instant feedback, and access to vast information resources (Zawacki-Richter *et al.*, 2019). The proliferation of these technologies has sparked significant interest in their potential to reshape pedagogical approaches and learning outcomes, marking a pivotal shift towards more data-driven and individualized education.

Within higher education, AI's perceived usage encompassing students' attitudes, acceptance, and frequency of interaction with AI tools has been identified as a critical factor influencing its educational impact. Research indicates that when students perceive AI tools as useful and easy to use, their adoption and integration into learning processes increase significantly, aligning with the Technology Acceptance Model (TAM) (Granić and Marangunić, 2019). This perceived utility is often linked to the belief that AI can alleviate academic burdens, facilitate deeper understanding

of complex subjects, and enhance essential cognitive skills. However, the relationship is complex; while some studies report positive correlations between AI usage and academic performance (Chiu *et al.*, 2023), others raise concerns about over-reliance and superficial learning, suggesting that the outcomes are heavily dependent on how these tools are utilized (Selwyn, 2022).

The relevance of AI proficiency extends beyond the immediate academic environment into the global economy and future workforce. The World Economic Forum (2020) has consistently highlighted complex problem-solving, critical thinking, and creativity as among the most crucial skills for the 21st century. In this landscape, AI is not merely a subject to be learned but a fundamental literacy, equipping graduates to navigate and innovate in an increasingly automated and data-rich world (Griffin, 2021). Consequently, there is a growing imperative for higher education institutions globally to integrate AI literacy and usage into their curricula, preparing students not just as consumers of technology but as adept practitioners who can leverage AI to solve real-world problems.

Despite this global momentum, the integration and study of AI in education within developing contexts, such as Nigeria, present a unique set of challenges and opportunities. While public universities in Niger State, like the Federal University of Technology Minna and Ibrahim Badamasi Babangida University Lapai, are increasingly exposed to digital learning tools, infrastructural constraints, varying levels of digital literacy, and cultural attitudes towards technology can influence the perceived usage and effectiveness of AI (Oyelere *et al.*, 2020). This context underscores the need for localized, empirical research to understand the specific dynamics of AI adoption and its pedagogical impacts, rather than relying solely on findings from technologically advanced environments.

Problem-solving skill, defined as the cognitive process through which individuals identify, analyse, and overcome obstacles to achieve a goal, is a cornerstone of academic and professional success (Jonassen, 2011). In undergraduate science and technology education, these skills are paramount, enabling students to apply theoretical knowledge to practical, often ill-structured, problems. The development of robust problem-solving abilities is strongly associated with deeper conceptual understanding, increased persistence, and enhanced innovation capabilities, all of which are critical for national development and technological advancement (OECD, 2018).

However, fostering advanced problem-solving skills remains a significant challenge in many educational systems. Traditional, didactic teaching methods, which are still prevalent, often prioritize rote memorization over the cultivation of higher-order thinking (Adigun *et al.*, 2022). This can leave graduates underprepared for the complex, interdisciplinary challenges they will face in their careers. In the specific context of Nigerian higher education, factors such as large class sizes and limited resources can further impede the individualised, inquiry-based instruction needed to develop these skills effectively (Fomunyam, 2020). Therefore, investigating innovative approaches, including technology-enhanced learning, to bolster problem-solving competencies is of critical importance.

The intersection of AI usage and the development of problem-solving skills represents a compelling and underexplored area of research. Theoretically, AI tools can scaffold the problem-solving process by providing simulations, data analysis capabilities, and iterative feedback that

would be difficult to achieve at scale through traditional means (Luckin *et al.*, 2022). For instance, AI can model complex systems, allowing students to test hypotheses and view outcomes in a risk-free environment, thereby enhancing their analytical and evaluative abilities. This positions AI not as a replacement for human cognition, but as a powerful cognitive partner that can augment and refine students' problem-solving strategies (Hwang *et al.*, 2020).

The empirical evidence regarding AI's impact on problem-solving skills is mixed and context-dependent. While some studies report significant improvements in students' analytical abilities and solution-generation creativity when using AI supports (Chiu *et al.*, 2023), others caution that passive or unguided use of AI can lead to cognitive offloading, where students bypass the critical struggle essential for developing deep problem-solving capacities (Selwyn, 2022). This ambiguity highlights a critical research gap, particularly in the Nigerian context, where the perceived value of AI and its actual impact on cognitive skills like problem-solving require systematic investigation.

Conclusion

Artificial Intelligence has come to stay in the contemporary world, existing researches provided some clues on its efficacy which debunk some of the misconceptions on its threats among nations. The authors concluded that AI is but a safe and adoptable tool in education and communication for the development of 21st century skills and effective teaching and learning among tertiary institutions in Nigeria.

Recommendations

Based on the discussion of this paper, it is therefore recommended that

1. More studies be carried out by learning institutions on the efficacy and ease of use of AI in academics
2. More conferences and workshops be organized by learning institutions, governmental and non-governmental bodies in Nigeria to discover more on AI and to uproot challenges for further actions
3. Governments and curriculum developers should develop and integrate structured AI literacy programs into undergraduate curricula.

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EFFECTS OF MULA ON ACADEMIC ACHIEVEMENT OF SECONDARY SCHOOL BIOLOGY STUDENTS IN NIGER STATE

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Abstract

This work investigated effects of MULA on academic achievement of secondary school Biology students in Niger State, two objectives, two research question and two hypotheses guided the study, the research design adopted for this work is quasi-experimental research design, the sample for the work was 402 Biology students using stratified sampling technique. The research instruments for this work were lesson plan and Genetics Achievement Test validated by four experts across Niger State. Genetics Achievement Test was pilot-tested on 40 Biology students in Niger State twice and pearson products moment correlation which yielded 0.82. This instrument was used to collect data. There collected were analyzed using special package for social sciences (SPSS). All the research were answered using mean and standard deviation while the null hypotheses were tested using Analysis for covariance ANCOVA. The results showed that students benefited from all the strategies but students benefited more from IBLA than conventional method. The work recommended that IBLA that improve students' achievement should be incorporated into Biology curriculum for better performance of Biology students across the nation

Keywords: MULA, IBLA, Achievement, Biology

Introduction

Science education aims to develop scientific literacy and understanding of the natural world, foster critical thinking, curiosity and problem-solving skills, prepare students for careers in Science, Technology, Engineering, and Mathematics (STEM), encourage informed decision-making and engagement with science-related issues in everyday life. Effective science education can inspire future generations of scientists, innovators, and citizens who can navigate the complexities of the modern world.

Biology is one of science subject. Biology subject stimulates intellectual curiosity, increases awareness of fragile ecosystem and stimulates critical-thinking (Martens 2019). Biology subject is a requirement for higher learning of science-related professional courses such as medicine, health sciences and agronomy, among others. However, in spite of the positive roles played by the science in general, the teaching and learning of Biology in particular has been unsatisfactory. Gimba *et al.*, (2018) has shown that students' achievement in Biology at the secondary school is not encouraging. Several factors have been reported to be responsible for the under achievement which includes among others; poor teaching method, inadequate instructional materials and lack of professional teachers. Consequently, the need to adopt some innovative strategies such as Modified-Useful Learning Approaches (MULA), Hypothetical-Predictive Reasoning Learning Cycle (HPR-LC) and Design-Based Learning (DBL) that are learners- centre. The study specifically adopted MULA because is the one that most suitable in dissemination of Biology concepts.

MULA is a combination of Learning-For Use (LFU) and Hypothetical-Predictive Reasoning Learning Cycle (HPR-LC) model that focus on integrating content and process, the learning is supported by different learning activities. This Learning 'For-Use Model' was developed by Edelson (2001) and Hypothetico – Predictive Reasoning by Lavoic (1999). It is also an innovative approach to teaching design using group learning, small group discussion, hands-on, laboratory activities, reflective thinking, discovery and inquiry learning to increase student's participation Marasigan *et al.*, (2017). MULA allows students to learn at their present level rather than failing to comprehend information above their understanding. The highlight of MULA is the use of hands-on and mind-on activities, unlike LFU model where computers are used in their learning activities in MULA laboratory activities, computers are not needed. Two strategies (inquiry-based learning and practical realia) was used with MULA while the conventional method was the control group which is also the independent variable in this study. The inquiry-based learning is one of the independent variable as well as experimental group.

Inquiry- based learning is a process that engages students by making real world connection and high level questioning. It helps students to make their own connections about what they learned. (Falloon 2020) also allows students investigate a phenomenon in a more authentic way similar to the way used by scientist. Inquiry-based activities increase the motivation of students because inquiry gives students freedom in making their choices, the opportunity to implement the regulation, and to take part in the project where they are involved. Overall, inquiry-based science education prove to be more fun and relevant, from several different aspects, for young students of science lessons and more fun than usual. Inquiry-Based Science Education (IBSE) proved could stimulate the motivation of students; students apply the skills of research, construct meaning and acquire scientific knowledge Suduc, *et al.*, (2015). As we strive to create a more engaging and effective learning environment, students are being engaged in activities using real objects for learning compare conventional teaching method.

Conventional teaching method, also known as the lecture-based or didactic approach, refers to a method of instruction in which the teacher transmits knowledge to students through lecture-discussion, reading, demonstration or other forms of presentation. Conventional teaching usually involves the teaching, giving information and tasks to the students, then expecting them to learn and understand it themselves (Doyle 2023). This teaching approach hinders students from being actively involved in their learning process by restricting them to passive listening. To resolve these challenges, it is necessary to abandon conventional teaching methods and instead embrace contemporary technique that involves students actively thereby making students to be independence in solving real life situations. (Lemo 2014) identified the weaknesses of the conventional instruction method (lecture method) learning achievement to be enhanced in science,. Achievement is a thing done successfully with effort, skill or courage and also a process of achieving something. The term is sometimes used as an indication of education quality within an educational system or when comparing group of schools. It has to do with the successful accomplishment of goal(s). The purpose of testing an achievement is to help the teacher and the students evaluate and estimate the degree of success attained in learning a given concept. It is also useful in testing the retention of information and skill. It is equally appropriate in determining the efficiency of instruction (Talal and Abeer, 2016). One of the issues at stake in education today is students' achievement measure in relation to teaching and the overall success of learning outcome, Use of guided- inquiry based teaching method in teaching simple machine by basic science

teachers may make Basic science lesson objective stimulating and interesting to the students. Kpolovie *et al.*, (2020), reviewed that students' academic achievement is the ability of the students to study and remember facts and communicate his knowledge orally or in a written form even in an examination condition. When students achieve better in education, this can also influence gender positively.

Gender bias is still prevalent in Nigerian schools ecosystem identified as one of the factors influencing students achievement and attitude to science subject at senior secondary school level (Salman 2016). Research findings on gender in achievement have been inconclusive, while some researchers have found no significant difference in academic achievement of male and female in science (Aaron 2014), others have found a significant effects of gender on students' achievement Iroko *et al.*, (2024). There are also different findings concerning the influence of gender on scientific reasoning skills and achievement of science students while others believe that gender influences scientific reasoning skills and achievement Piraksa. *et al.* (2014). These inconsistent findings have called for the inclusion of gender. School location was also considered as moderating variable in this study.

Statement of Problem

In recent years, the persistent decline in students' academic achievement in Biology at the secondary school level in Niger State has become a major concern to educators, parents, and policymakers. Despite the importance of Biology as a foundational science subject that prepares students for careers in medicine, agriculture, and biotechnology, many students continue to perform poorly in both internal and external examinations such as WAEC and NECO. Studies and reports from the West African Examinations Council (WAEC, 2022) have consistently shown that a significant percentage of candidates fail to demonstrate adequate understanding of key biological concepts. This poor performance has often been attributed to ineffective teaching methods, low learner engagement, and insufficient use of innovative instructional tools.

Traditional teacher-centered methods commonly employed in Biology classrooms in Niger State tend to emphasize rote learning and memorization rather than active participation and conceptual understanding. This approach limits students' opportunities to explore, discuss, and apply biological concepts to real-life situations. Consequently, many students find Biology abstract, difficult, and uninteresting, leading to low achievement and poor retention of knowledge.

In an effort to improve learning outcomes, modern learning approaches such as Mobile-Assisted Learning Applications (MULA) have been introduced to enhance teaching and learning processes. MULA integrates mobile technology into instruction, allowing learners to access interactive content, simulations, quizzes, and videos that promote self-directed and experiential learning. However, the adoption and effectiveness of MULA in improving academic achievement in Biology among secondary school students in Niger State remain largely under-researched. It is unclear whether the use of MULA significantly enhances students' understanding and achievement compared to traditional instructional methods.

Therefore, the problem of this study is to determine the effects of MULA on the academic achievement of secondary school Biology students in Niger State.

Purpose of the Study

The aim of this study is to investigate the effects of MULA on the academic achievement of secondary school Biology students in Niger State. The following objectives guide this study

1. Determine the effects of MULA on Biology students' achievement in Niger state
2. Examine influence of gender on MULA on Biology students' achievement in Niger state

Research Questions of the study

1. What is mean achievement difference scores of Biology students taught using MULA and those Biology students taught using conventional method?
2. What difference in the mean achievement scores of male and female Biology students taught using MULA in Niger State?

Research Hypotheses

H0₁: There is no significant difference in mean achievement scores of students taught Biology using MULA and those taught using conventional method

H0₂: There is significant difference in the mean achievement scores of male and female Biology students taught using MULA

Research Methodology

The research adopted non-randomized experimental and control groups, pretest-posttest and non-equivalent quasi-experimental research design.

Table 1 Quasi-Experimental Design Layout

Groups	Pre-test	Treatment	Post-Test
Experimental 1	O ₁	X ₁	O ₂
Experimental 2	O ₁	X ₂	O ₂
Control	O ₁	X ₀	O

Where:

O₁ – Treatment with Pre-test Instrument

O₂ – Treatment with Post-test Instrument

X₁ X₂ – Treatment for Experimental Groups 1 and 2

The population of the study comprises fifty-two thousand five hundred and forty-eight students (52,548) which comprises of twenty seven thousand two hundred and seventy-three (27, 273) male and twenty five thousand two hundred and seventy –five (25,275) female of all Senior Secondary Schools SS1-SS111 Biology students of 2024/2025 session in Niger State, Nigeria. The sample for this research was four hundred and two students (402) comprised of two hundred and thirty-eight (238) male and one hundred and sixty- four female drawn from nine co-educational senior secondary schools randomly through a stratified sampling technique through the three (3) senatorial zones (A,B and C). The instrument for this research were lesson plan and Biology achievement test. These instruments were validated by four Biology experts in Niger State. The validity of Biology achievement test was determined by pilot-testing the Biology achievement on 40 biology students in SS II twice, this data obtained was analyzed using Person Product Moment Correlation Co-efficient which yielded 0.82. These instruments were used to gather data from Biology students across Niger State. The data gathered were analyzed using statistical package for

social sciences (SPSS). The research questions were answered with mean and standard deviation while the hypothesis were tested using ANCOVA.

Results.

Research Question one: What is the difference in the mean achievement scores of students taught genetic concept using IBLA and those taught with control?

To answer this research question, mean and standard deviation were used and the results presented in Table 2.

Table 2: Comparison of the Mean and Standard Deviation of Pre-test and Post-test results for IBLA and Control Groups

Group	Pre-test		Post-test		Mean Gain	Mean Difference
	N	$\bar{x}$	SD	$\bar{x}$	SD	
IBLA	113	13.00	4.10	29.00	15.00	16.00
Control	127	11.00	3.00	11.00	3.11	0.00

The Table 2 shows the mean and standard deviation analysis of pre-test and post-test scores of IBLA and the control group on achievement in genetics concepts. The Table revealed that mean and standard deviation scores of the pre-test and post-test of IBLA group are $\bar{x}=13.00$, SD 4.10 and $\bar{x}=29.00$, SD = 15.00 respectively given a mean gain scores of 16.00. While the control group has the mean and standard deviation of pre-test and post-test scores are; $\bar{x}=11.00$, SD = 3.00, and $\bar{x} = 11.00$, SD = 3.11 given a mean gain of 0.00. The results revealed that IBLA group and control group had mean gain of 16.00 and 0.00 respectively with mean difference of 16.00 in favour of IBLA having the highest mean gain. This implies that IBLA was more effective in

Research Question Two: What is the difference in the mean achievement scores of male and female students taught genetics concepts using IBLA and those taught with conventional lecture method. To answer this research question, mean and standard deviation were used and the results presented in Table 3.

enhancing student achievement in genetics than the control method.

Table 3 Comparison of Mean and Standard Deviation of Pre-test and Post-test Results of Students Taught Genetics Concepts Using IBLA and Conventional Lecture Method

IBLA and Control	Pre-test		Post-test		$\bar{x}$ Gain	$\bar{x}$ Difference
	N	$\bar{x}$	SD	$\bar{x}$	SD	
Male IBLA	76	11.00	3.01	26.12	8.00	15.12
Male Control	69	11.00	2.50	11.10	3.00	0.10
Female IBLA	86	11.00	3.00	29.40	9.00	18.40
Female Control	68	10.40	3.25	11.00	3.50	0.60
Total	289					

Table 3 shows the mean and standard deviation analysis of pre-test and post-test scores of male and female taught genetics concepts using IBLA group and the control group. The Table revealed that mean and standard deviation results of the pre-test and post-test of male IBLA and male control are; $x = 11.00$, $SD = 3.01$ and $x = 26.12$, $SD = 8.00$ respectively given a mean gain of 15.12 and; $x = 11.00$, $SD = 2.50$ and $x = 11.10$, $SD = 3.00$ respectively given a mean gain of 0.10 respectively. While the mean and standard deviation of pre-test and post-test of female IBLA and female control result of students are; $x = 11.00$, $SD = 3.00$, and $x = 29.40$, $SD = 9.00$ given a mean gain of 18.40 and ; $x = 10.40$, $SD = 3.25$, and $x = 11.00$, $SD = 3.50$ given a mean gain of 0.60 respectively. The result revealed that male IBLA group and male control group had mean gain of 15.12 and 0.10 respectively with mean difference of 15.02 in favour of the male IBLA group having the highest mean gain. Also the result revealed that female IBLA group and female control group had mean gain of 18.40 and 0.60 respectively with a mean difference of 17.80 in favour of the female IBLA group having the highest mean gain. This implies that IBLA is gender friendly with female having the highest mean gain performing better than male and it also affect them positively in their performance.

Research Hypothesis One: There is no significant difference in the mean achievement scores of students taught genetics concepts using IBLA and those taught with conventional lecture method. To test this hypothesis ANCOVA was used as presented in Table 4.

Table 4: ANCOVA Analysis of Achievement scores of Students Taught Genetics Concepts using IBLA and Control

Source	Type III Sum of Squares	df	Mean Squares	F	Sig.
Corrected Model	19938.00	2	9969.95	91.41	0.00
Intercept	6061.00	1	6061.00	56.00	0.00
PRETEST	101.12	1	101.12	1.00	0.34
GROUP	17418.30	1	17418.26	160.00	0.00
Error	25846.10	237	109.10		
Total	133874.00	240			
Corrected Total	45784.00	239			

Table 4 shows the ANCOVA analysis of mean achievement scores of students taught genetics concept using IBLA and control the result revealed that $f = (1,239) = 160.00$, $p = 0.00$ ($p < 0.05$). Since p -value of 0.00 is less than 0.05 level of significant, the results shows that there was significant different in the mean achievement scores of students taught genetics concept using IBLA and those taught with control. The null hypothesis one was therefore rejected on the basis that the main effect (treatment) was significant, therefore Sidak post-hoc test analysis was carry out to identify the direction of the difference among the treatment groups as shown in Table 5.

Table 5: The Sidak post- hoc Analysis of the Groups Mean Scores of IBLA and Control

(I) Group	(J) Group	Mean (I- J)	Dif	Std Error	Sign ^b	95% Interval Difference ^b	Confidence for
						Lower Bound	Upper Bound
IBL	CON	18.00*		1.41	.01	15.044	20.601
CON	IBL	-18.00*		1.41	.01	-20.601	-15.044

Sidak post-hoc analysis on Table 5. indicated that the observed significant difference was between IBLA and control with the mean difference of 18.00, p – value of $(0.01) < (0.05)$ was significant. The mean difference here is in favour of IBLA, therefore, hypothesis one is hereby rejected.

There is no significant difference in the mean achievement scores of male and female students taught genetics concepts using IBLA and those taught with conventional lecture method. To test this hypothesis ANCOVA analysis was used as presented in Table 6

Table 6: ANCOVA Analysis of Achievement scores of Male and Female Students Taught Genetics Concepts with IBLA and Control

Source	Type 111 Sum of Squares	df	Mean Squares	F	Sig
Corrected Model	21732.00	4	5433.00	130.10	0.00
Intercept	3744.30	1	3744.30	90.00	0.00
PRETEST	578.00	1	578.00	14.00	0.00
GENDER	21027.43	3	7009.14	168.00	0.00
Error	11863.50	284	42.00		
Total	153189.00	289			
Corrected Total	33595.10	288			

Table 6 shows the ANCOVA analysis of mean achievement scores of male and female students taught genetics concept using IBLA and control the result revealed that $df = 3$, $f = 168.00$, $p = 0.00$ ($p < 0.05$). Since p - value of 0.00 is less than 0.05 level of significant, the results shows that there was significant different in the mean achievement scores of students taught genetics concept using IBLA and those taught with control. The null hypothesis was therefore rejected.

Summary of Finding

1. The findings revealed that Inquiry-based learning approach was very effective in enhancing students' achievement in genetics concepts better than the conventional lecture method where Inquiry-based learning approach had the highest mean gain. There was significant difference in the mean achievement scores of students taught genetics concepts using Inquiry-based approach and conventional lecture method

2. The results revealed that Inquiry-based learning approach was gender friendly, for it enhances both male and female mean achievement scores and affected them positively in genetics concepts, but there was mean difference in favour of female students.

Discussion of Findings

The finding on the effects IBLA on Biology students' achievement shows that there was significant difference in the mean achievement scores of students taught Biology using IBLA and those taught using conventional method. This findings concurred with the findings of Aktamis *et. al* (2016) who worked on effects of inquiry based learning strategy on secondary schools students' misconception of science concepts and finally discovered that inquiry strategy improve students' achievement when taught using inquiry strategy, it also corroborated with findings of Abidoye (2018), Alachi *et. al.*, (2021) but go against the findings of Abdi (2014). The findings also shows that IBLA is gender friendly, this finding also support the findings of Casmir (2019) but go against the findings of Aktamis *et al.* (2016) who says gender has serious impact on the use of inquiry strategy in the classrooms

Conclusion

The research study investigated the Effects of Modified-Useful Learning Approaches on Secondary School Biology Students' Achievement, in Niger State, Nigeria. From the finding of the research study and discussion that followed, the following conclusion were made:

Inquiry-based Learning approach is very effective in enhancing the academic achievement in genetics concepts among secondary school Biology students in Niger State, Nigeria. It might be because the approaches were active methods of teaching that allowed students' participation in the teaching and learning instruction and it is gender friendly.

Recommendations

Based on the findings of this study, the following recommendations were raised: Science teachers should incorporate the idea of using Inquiry-based learning instructional approach in teaching science subjects in secondary schools since the study have shown that the students taught with this approach perform much better in achievement

Another recommendation is that, the experimental approach was gender friendly because there was no significant difference in the mean achievement scores of male and students taught with the experimental group. Therefore, it is recommended the strategy should be use as a means of disseminating learning instructions in secondary schools in order to reduce the gap in the performance of male and female students.

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STRENGTHENING ICT ADOPTION IN PUBLIC SCHOOLS: INFRASTRUCTURE, POLICY, AND IMPLEMENTATION CHALLENGES IN NIGER STATE, NIGERIA

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Abstract

This research investigates the availability and adoption of Information and communication technology (ICT) infrastructure among public schools in Niger State, Nigeria. The findings show that despite all happening in the era of Artificial Intelligence, policies and programs put in place by the government of Nigeria, UNICEF, and other agencies across the globe to bridge the ICT gap in the public schools of most underdeveloped nations of the world, most of the public schools in Niger state, Nigeria, cannot boast of ICT infrastructure and as a result, are not able to measure up to the privately owned schools in the same state simply because of the unavailability of ICT infrastructure. Out of the 110 schools assessed in this study, ICT infrastructure was available only in 14 of these public schools, while ICT infrastructure was not available in 96. Among the 14 public schools where ICT infrastructure was available, only 6 of these public schools have adopted the ICT infrastructure for learning and teaching. The remaining eight (8) only use their ICT infrastructure for administrative purposes. For the public schools to measure up to privately owned schools, the government of Niger state will have to invest in ICT infrastructure, employ competent teachers and pay them favorable salaries, deploy surveillance cameras to monitor the activities around the computer laboratory, provide power supply, and set up a maintenance and continuity plan to keep the public schools running optimally.

Keywords: *ICT, Infrastructure, Public Schools, Policy, Implementation.*

Introduction

Nigeria operates a federal system of government consisting of 36 states and the Federal Capital Territory Abuja. Within the states, there are a total of 744 local governments. Federal, state, and local governments administer education. The Federal Ministry of Education is responsible for overall policy development and quality control, but mainly in relation to higher education. Secondary education is primarily the responsibility of state (secondary) and local (elementary) governments. According to the National Education Policy of the Federal Ministry of Education of Nigeria, basic education consists of nine years of formal compulsory tutelage, including six years of primary education and three years of secondary schooling. Post-primary education includes three years of high school.

According to the Federal Ministry of Education, National Policy on Information and Communication Technologies (ICT) in education in Nigeria, 2019, developments in the Nigerian education sector indicate some level of ICT availability, adoption, and application in public

schools. The Federal Government of Nigeria, in the National Policy on Education (Education, 2019), recognizes the prominent role of ICT in the modern world and will integrate ICT into education in Nigeria. The document states that the government will provide basic infrastructure and training at the primary school to actualize this goal. At the junior secondary school computer education will be made a pre-vocational and vocational elective at the senior secondary school. It is also the intention of the government to provide the necessary infrastructure and training for integrating ICTs in the public school system.

One of UNESCO's overarching goals is to ensure that all developed and developing countries have access to the best educational facilities needed to prepare their young to fulfill their roles in modern society and contribute to a world-class country. Maintain the ability to advise national governments on the use of technology in schools, particularly on the optimal balance, appropriate to local circumstances, between IT and older educational technologies, and help countries develop educational software and hardware that reflect their national and regional needs. Culture is a key element in the Organization's strategy to achieve the goal of education for all (Sharma & Dahiya, 2016). Information Information and communications technology (ICT) has become a trend in global socio-economic issues. It has become more important than ever in any country, organization, or institution, no matter how high or low they want to define and apply it. Today's world is driven by knowledge, and the information age is at the center of almost everything. Therefore, IT facilities are essential for providing quality educational services in secondary schools (Onu & Ezhim, 2019). (Henderson, 2020) suggests that some benefits of using ICT in the classroom include improved engagement, improved knowledge retention, and increased individualized learning.

To appreciate the degree of penetration of information technology into our daily lives, imagine a day without computers. This day will be the day without medical imaging or robot-assisted surgery; a day when cars lack anti-lock brakes, electronic stability control, or other driving aids; a day without digital maps, traffic information, or navigational instructions; a day without digital media – no online music or video, computer animation or video games; a day without online education or telemedicine; a day when planes cannot fly, travelers must navigate without the aid of the global positioning system "GPS", meteorologists have no prediction models, banks and merchants cannot electronic money transfers and factory production stopped. For most people in the United States and the rest of the developed world, it will be a "day the Earth stood still." (Mynatt *et al*, 2020) However, in Nigeria, we have a lot of organizations and agencies that are not interested in using technology information. Niger State is one of the largest states in Nigeria, covering about 86,000 km² (or about 8.6 million hectares), representing about 9.3% of the total land area of the country. Niger state boasts of at least 300 public schools, which comprise primary and secondary across all her 25 local governments (Statista, 2022), but most of the students in public schools in Niger state and the north in particular performs poorly (Ibrahim, 2019). Could it be because most of the public schools in northern Nigeria are not ICT compliant after all, despite all the investments and policies put in place to boost education in the public schools across the country?

Problem Statement.

ICT is considered a viable means of promoting economic development. There is an uneven distribution of IT adoption and implementation across Nigeria. Rural areas seem to lag behind

urban centers. Urban centers also have a gap between ICT adoption in public and private schools (Ogundile *et al.*, 2019). It is known that applying ICT to facilitate teaching and learning activities in public schools can significantly improve student learning outcomes. However, many public schools in Nigeria have yet to implement IT infrastructure. As a result, this significantly impacts student performance (Ibrahim, 2019). Secondary schools in Nigeria have not used information technology in teaching; it is not part of the skill taught to students, even though it is one of the subjects in the country's high school curriculum. Schools use computers for simple administrative tasks rather than for the teaching and learning process (Abdulatef *et al.*, 2016). Therefore, this study aimed to investigate the availability and adoption of ICT in public schools in Niger State. This study aims to investigate the availability of ICT infrastructure in the public schools in Niger state and the levels of use in the schools by evaluating the availability and level of adoption of ICT tools and practices in the assessed public schools.

Research Questions

- i. Are there ICT infrastructure (at least computers) in the public schools?
- ii. What essentially is/are the ICT infrastructure used for?
- iii. Has the school embraced and adopted the use of ICT?

Literature reviewed

Gana *et al.* (2023) assessed the impact of Information and Communication Technology (ICT) on the activities of the Niger State Judicial Library. The objectives of their study were to investigate the availability of ICT resources and to verify the ICT services offered in judicial libraries across the state. A descriptive research design was employed, and data were collected from eighteen (18) library professionals. Based on the findings and discussions, the study made several recommendations, including advising library administrators to secure funding to better equip libraries, recruit skilled staff, ensure the optimal management of library ICT facilities, provide adequate IT training for existing staff, promote IT-based library resources and services, and develop flexible IT policies. The study concluded that ICT use in these libraries was poor, emphasizing that without the proper application of ICT tools, library operations would remain inefficient. Similarly, Ahmed (2021) evaluated the impact of ICT on the management of state institutions of higher learning in Niger State, Nigeria. Five objectives guided the study, two of which were to assess the impact of ICT on record retention in higher education institutions and to evaluate the influence of ICT on educational research. The study formulated five null and five core hypotheses. A descriptive research design was adopted, with a population of 15,308 individuals, comprising 50 institutional leaders, 8,000 academic staff, and 7,258 non-academic staff. Using a purposive sampling technique, a total sample of 365 respondents was selected. Data were collected through a self-developed questionnaire consisting of fifty (50) modified structured statements rated on a five-point Likert scale. The research findings revealed that ICT was widely adopted and significantly facilitated communication between different management levels and staff. ICT also enabled proper record-keeping, with records effectively stored and easily retrievable for future use. The study concluded that the introduction of ICT had eliminated the challenges associated with manual record searches, document management, and physical storage limitations in institutions of higher learning. Consequently, it recommended the provision of more high-quality ICT facilities across higher institutions, as well as regular staff training in archival practices, record preservation, and decision-making processes through ICT. In a related study, Izom *et al.* (2022) evaluated the effectiveness of ICT in the training of teachers in higher education institutions in

Minna. The study employed a descriptive survey design, utilizing both experimental and qualitative data collection methods. A total of 120 paper-based questionnaires were distributed to teachers, achieving an average response rate of 90%. The study revealed several key findings: teachers had limited access to ICT devices for both teaching and administrative purposes; while many teachers demonstrated considerable expertise in integrating ICT into teaching and learning, there remained a significant need for capacity-building initiatives. It was also observed that although middle school teachers attempted to integrate ICT into their activities, this integration rarely extended into actual classroom teaching. Moreover, the State Department of Education's policy on ICT integration had not been adequately implemented. Overall, the level of ICT integration among teachers was found to be low, hindered by multiple challenges, particularly inadequate government commitment and weak policies. The study notably focused on tertiary institutions, leaving a knowledge gap regarding ICT adoption in public schools.

Finally, Jacob (2020) investigated the barriers to ICT adoption in public primary schools across Nigeria and proposed strategies for moving forward. The study identified that public elementary school students faced numerous challenges related to ICT integration into their learning programs. Using coverage from print and online publications, the research highlighted obstacles such as insufficient funding for IT programs, inadequate IT facilities, poor internet connectivity, unstable power supply, the high cost of IT infrastructure, a shortage of trained ICT teachers, weak implementation of ICT initiatives, scarcity of ICT learning materials, low student ICT skills, corruption, and insecurity. To address these issues, the study recommended that the government increase funding for ICT programs in all public elementary schools and ensure nationwide availability of quality internet services. However, this study left a gap in knowledge regarding whether ICT infrastructure was actually available in the primary schools included in the research. A study by Fakunle et al. (2022) asserted that the application of ICT in children's daily activities had enabled humanity to achieve remarkable feats once considered unattainable centuries ago. These achievements were evident across sectors such as healthcare, education, connectivity, the economy, and religious practices. The study also highlighted a noticeable gap between the extent to which individuals in developed and developing countries adopted ICT in their daily lives. Consequently, the primary objective of this systematic review was to investigate the current state of ICT usage among Nigerians and to examine the socio-cultural, economic, and technical factors influencing its prevalence, feasibility, and acceptance within the country. To achieve this aim, the researchers systematically searched and organized previously published relevant studies—primarily indigenous research—spanning from 2015 to 2021. They integrated findings from qualitative, quantitative, empirical, and theoretical research on the topic. The review found that ICT was utilized in various areas, including higher education, relationship maintenance, healthcare support, safeguarding relatives, and religious and economic activities among Nigerians. The study concluded that while ICT usage had been widely accepted in social activities across the country, its adoption faced challenges from socio-cultural, economic, and technical barriers. However, it is important to note that the study did not address the availability or adoption of ICT infrastructure in public schools, particularly in northern Nigeria. This omission left a significant knowledge gap, which my research seeks to address. Adewoye and Salau (2021) employed a simple random sampling technique across three selected public universities in Lagos, Ogun, and Oyo States. Out of 300 questionnaires distributed, 234 were completed and returned. The researchers conducted data analysis using the Pearson Product-Moment Correlation Coefficient (PPMCC) and multiple regression analysis. The findings revealed a positive relationship between ICT usage and teaching

and learning in Nigerian universities. The study concluded that ICT provided significant opportunities for enhancing teaching and learning and that factors influencing ICT adoption—such as personal characteristics, organizational capabilities, support systems, and availability of resources—positively impacted these educational processes. Based on these results, the authors recommended that Nigerian universities should improve their organizational capacity, particularly regarding funding and infrastructure, and should continue promoting ICT use in teaching and learning. However, the study did not explore ICT usage in public primary or secondary schools, a gap that this study seeks to address.

Similarly, Gwangwazo (2021) highlighted how the rapid advancement of Information and Communication Technology (ICT), particularly during the COVID-19 pandemic, compelled many nations to integrate ICT into teaching and learning processes. The research aimed to identify key factors encouraging ICT adoption in Nigerian schools and proposed a conceptual framework to assist policymakers in promoting ICT acceptance among teachers in both public and private schools. Additionally, the study identified challenges such as poor electricity supply, limited internet access, and inadequate technological infrastructure, which hindered the effective adoption of digital learning in Nigeria during the pandemic. Although the study focused on factors influencing adoption in selected secondary schools in Gombe State, it did not address the availability of ICT infrastructure, a gap that this study seeks to address. Teye et al. (2022) examined the contextual factors influencing ICT adoption and usage by school administrators in referral districts of Ghana. A cross-sectional survey design was adopted, with data collected from 69 participants using census sampling methods and analyzed through multiple regression techniques. The study found that five out of six factors—attitudes toward ICT, perceived usefulness of ICT tools, access and availability of ICT tools, training and technical support, and motivation and incentives—were significantly associated with ICT adoption. Motivation and incentives were the strongest predictors ($\beta = 0.496$) of ICT adoption and use. Interestingly, perceived ease of use was not a significant predictor. The study recommended that school administrators receive sufficient training, technical support, and motivational incentives to enhance ICT integration. Although the study focused on basic schools, it did not address the availability of ICT infrastructure, which this study seeks to address. Dean Henderson (2019) emphasized the critical role of ICT in supporting educational activities and highlighted that educators had developed various strategies to incorporate technology into teaching and learning. Henderson argued that ICT significantly enhances learning efficiency and enriches the teaching experience. Technology was also noted as a powerful tool for expanding students' knowledge, fostering independent thinking, enhancing creative communication, and preparing students for success in a technology-driven world. However, Henderson's work primarily focused on the broader benefits of ICT integration and did not address the realities of ICT availability in public schools, leaving a gap we seek to address.

David (2017) investigated the impact of ICT adoption on the educational growth of colleges of education in Agbor and Warri, Delta State, Nigeria. Research questions were formulated to guide the study, and a questionnaire was administered to a sample of 126 non-academic staff members, representing 50% of the target population. After thorough data analysis, the study found that colleges of education in Agbor and Warri had access to various ICT facilities, including the internet, computers, printers, photocopiers, scanners, DVD players, and intercom systems. The benefits of ICT use included efficient document processing and storage and the digitization of

school administrative processes. However, challenges such as inadequate funding, low investments in ICT, and limited ICT literacy among staff were identified. The study concluded that higher education institutions must leverage available information sources to overcome barriers to effective ICT integration. Like several others, this study focused on tertiary institutions, leaving a knowledge gap regarding ICT infrastructure in public primary and secondary schools—a gap this study seeks to address.

Research Methodology

In this study, we adopted a descriptive research approach due to its flexibility and suitability for the set objectives. Quantitative method was adopted to collect and analyze the data obtained. A total of 110 schools were visited and responses were collected via a google form questionnaire (<https://bit.ly/ict-availability-adopted>), titled “ICT Availability and Adoption among public schools in Niger state”.

The developed questionnaire served as the main instrument in collecting data for this study. Minna, being the state capital, we expect to reflect what is obtainable in other local government areas. The questionnaire includes two (2) sections. Section A captured the name, addresses and other details of the public schools, while Section B comprised questions to address the set objectives of the study.

Results and Discussion

Results

Out of a total of 110 public schools in various parts of Niger state, the following were discovered. From the research questions.

Table 1: Are there ICT infrastructure in the public schools?

	Presence of ICT infrastructure	Number of public schools	Percentage (%)
1	YES	14	12
2	NO	96	88

Table 1. Showing the numbers of public schools with and without ICT infrastructure

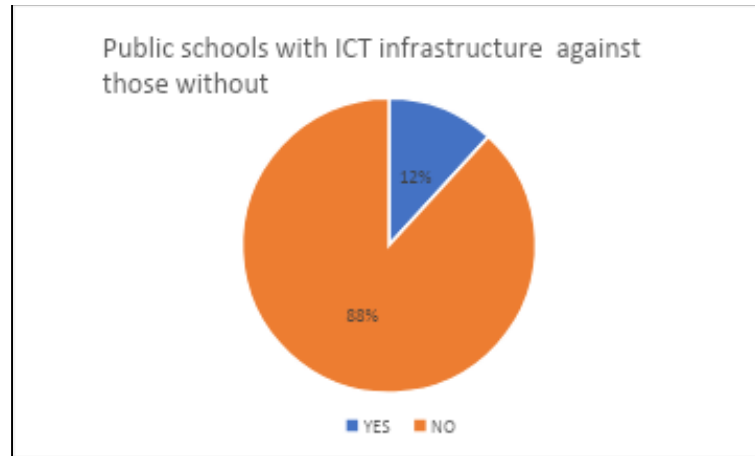


Figure 1. Pie chart showing the percentage of public schools with ICT infrastructure and those without ICT infrastructure.

Table 2: What essentially is the ICT infrastructure used for?

	Uses of ICT infrastructure	Number of public schools
1	Admin Task	8
2	Admin, Teaching, Learning	6
3	No Infrastructure	96

Table 2 showing the number of public schools and what they do essentially with their ICT infrastructure and those without infrastructure

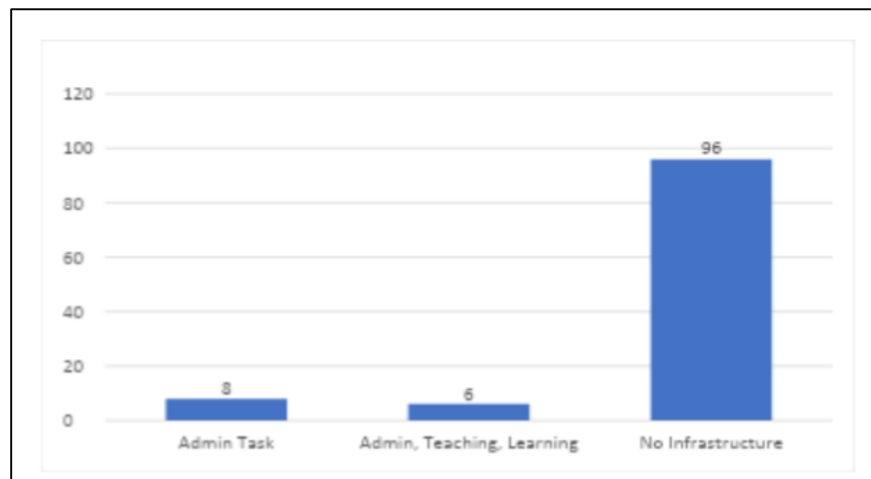


Figure 2 showing the chart of public schools and how they use their ICT infrastructure.

Table 3: How many public schools have embraced and adopted the use of ICT?

S/N	Adopted ICT	Number of public schools	Percentage (%)
1	YES	6	5
2	NO	104	95

Table 3 showing number of public schools who have embraced and adopted the use of ICT.

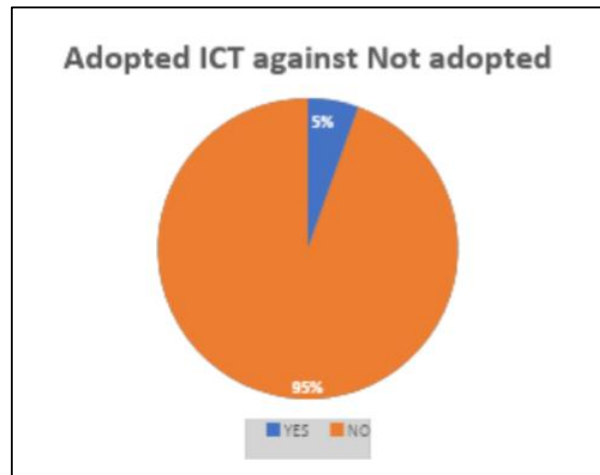


Figure 3. Pie chart showing the percentage of public schools who have adopted ICT against those who have not adopted ICT

Findings of the Study

- i. Some public schools in the state capital with ICT laboratories reported previously owning computers and printers, but these devices started disappearing with no one held accountable.
- ii. A few of the public schools with ICT infrastructure had not adopted ICT for teaching and learning because they did not have competent instructors who could teach the students.
- iii. A few other schools had not adopted ICT because the available computers had broken down with no one available to fix them.
- iv. A few other schools had not adopted ICT because they had an incomplete set of computer systems. For instance, some had monitors without CPUs, some had monitors and CPUs but no mouse and keyboard, and others had no CPUs.
- v. Virtually all the public schools outside the state capital do not have any ICT infrastructure because the schools are not connected to the power lines and hence cannot accommodate any electronic infrastructure.

Discussion of Findings

It is quite unimaginable, from Table 1, that out of 110 schools that were assessed based on the availability or presence of ICT infrastructure, only 14 of these public schools own at least 1 to 5 computers and printers, while 96 of these public schools in the state capital and other local government do not own even a computer. The Pie chart also reveals that only 12% of the 110 public schools own ICT infrastructure, while 88% do not have access to ICT infrastructure. From Table 2, we see that out of the 110 public schools assessed on how the ICT infrastructure is employed, 8 of the public schools that have at least 1 to 5 computers and printers make use of their computers and printer for typing and printing of examination questions and other administrative works, 6 of them makes use of their ICT infrastructure for both administrative work and also teaching the students of the school the use practical uses of the ICT infrastructure. Ninety-six (96) of the 110 schools do not have any infrastructure and hence do not use any ICT infrastructure, as seen on the bar chart. Table 3 summarizes the public schools that have embraced and adopted ICT in their operations and administrations and those that have not. Out of the 110 public schools, only 6 out of the 14 schools with ICT infrastructure, which is equivalent to 5%, have adopted the use of ICT, while the remaining eight (8) public schools with computers and printers, in addition to the 96 without any form of ICT infrastructure have not adopted ICT in their daily operations and administration.

Conclusion

It is disturbing to know that despite all the policies and programs put in place by the government, UNICEF, and other agencies have had little to no impact. Most of the public schools in Niger state do not have ICT infrastructure and are not able to measure up to the private schools in the same state simply because of the unavailability of ICT infrastructure. The cause of this unavailability from this study can be linked to the government not measuring up to her responsibilities by providing, securing, monitoring, and promoting the ICT infrastructure. Also, part of the blame can be attributed to the personnel in these public schools choosing not to embrace technological innovations and advancement. This disturbing status of the public schools in the state can be changed when the state government assumes her position, deploys ICT infrastructures to the public schools, employs competent computer teachers, and monitors the progress and development of the public school schools.

Recommendations.

For public schools in Niger state to become ICT compliant, the state government, in addition to investing in ICT infrastructure, will have to implement the following:

- i. Relevant personnel in public schools should be made accountable and responsible for ICT investment in the schools. The computer laboratory should be physically secure, deploying surveillance cameras to monitor the activities and movements in and around the school premises to forestall any attempts at stealing the ICT infrastructure.
- ii. Competent computer instructors should be recruited and paid competitive salaries to ensure effective and efficient service delivery.
- iii. Sign a maintenance agreement with an ICT company that will always maintain all the computers and the parts and replace them whenever they become bad so there will be continuity in the use of the infrastructure.

- iv. Set up a committee of IT auditors that will always audit all the infrastructure in the public schools so that at every point in time, there will be real-time information concerning the infrastructure in every public school in the state.
- v. Make an effort for all public schools, irrespective of their location, to be connected to the power lines so that they can power ICT infrastructure.

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AN OPTIMIZED MACHINE LEARNING APPROACH FOR POLYCYSTIC OVARY SYNDROME DETECTION: A FRAMEWORK

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Abstract

Research interest in employing machine learning algorithms to develop models for detecting Polycystic Ovary Syndrome (PCOS) has increased significantly in recent years. This surge is understandable, as the condition mostly affects reproductive age women, and is a major cause of infertility. Consequently, researchers employ Machine Learning techniques to address this ailment. However, issues of accuracy and optimal results are still major issues to contend with using this technology owing to the complexity of the medical dataset. This study proposes to detect PCOS considering Support Vector Machine, K-Nearest Neighbour, and Extreme Gradient Boost approaches with the aid of Red Deer Algorithm (RDA). Therefore, other optimization algorithms and machine learning models can be deployed to validate the efficiency of the developed model.

Keywords: *Red Deer Algorithm (RDA), Polycystic Ovary Syndrome (PCOS), Support Vector Machine (SVM), K-Nearest Neighbor (KNN), Extreme Gradient Boost (XGBoost).*

Introduction

Polycystic Ovary Syndrome (PCOS) is a health disorder that affects fertility in women, with its impact most evident during the reproductive years, though it can also extend into the perimenopausal stage (Swamy & Nandini, 2022). Polycystic Ovary Syndrome (PCOS) is an endocrine condition that affects the ovaries of women between the ages of 15 and 45, with a prevalence rate of 5–10% among women of reproductive age (Harish *et al.*, 2023). This disease is a complex and chronic endocrine disorder characterized by symptoms such as irregular menstruation, infertility, hirsutism, acne, and obesity (Asghari *et al.*, 2022 ; Gomez *et al.*, 2022; Guan *et al.*, 2022 ; Gleicher *et al.*, 2022). Excess androgen levels and ovarian dysfunction are the two main hallmarks of Polycystic Ovary Syndrome (PCOS). Its development has been linked to multiple factors, including genetics, puberty, physiological changes, psychological health, and environmental influences. Globally, the prevalence of PCOS ranges between 2.2% and 20%, depending on the population studied and the diagnostic criteria used (Sutaji *et al.*, 2022).

Polycystic Ovary Syndrome (PCOS) is linked to multiple endocrine and metabolic abnormalities that impair fertility, although its precise cause remains uncertain. Affected women frequently experience challenges in conceiving and face elevated risks of miscarriage, gestational diabetes, preeclampsia, pregnancy-induced hypertension, and increased fetal morbidity compared with women without PCOS. Beyond its critical role in glucose metabolism, insulin also influences reproductive processes. In PCOS, insulin resistance and the resulting hyperinsulinemia are major contributors to infertility and poor pregnancy outcomes (Rahman *et al.*, 2024).

A range of clinical approaches, such as in vitro fertilization (IVF), have been introduced to treat infertility. Nevertheless, the rising worldwide demand for IVF highlights infertility as a significant public health issue. Inaccurate diagnoses often lead couples to undergo multiple unsuccessful IVF

attempts, increasing both the health risks and financial strain for women. Polycystic Ovary Syndrome (PCOS), a multifactorial disorder involving metabolic, reproductive, and endocrine dysfunctions, is among the leading causes of infertility in premenopausal women (Hussein & Karami, 2023). To achieve accurate and reliable detection of disease symptoms, many research efforts have focused on utilizing advanced technologies powered by artificial intelligence and machine learning models.

Artificial intelligence (AI), especially machine learning models, constitutes an innovative technology capable of classifying and detecting the risk of Polycystic Ovary Syndrome (PCOS). These models include XGBoost, K-Nearest Neighbor (KNN), Support Vector Machine (SVM), Logistic Regression (LR), Naïve Bayes (NB), Random Forest (RF), and Multi-Layer Perceptron (MLP) (Kumari *et al.*, 2023 ; Mou *et al.*, 2023; Prasher *et al.*, 2023; Jaiswal *et al.*, 2024 ; Kumar *et al.*, 2024). Understandably, numerous researchers have attempted to utilize these models repeatedly for accurate disease detection using the data at available. Nevertheless, variations within the datasets have hindered precision and led to biased performance outcomes.

However, due to the inherent characteristics of medical datasets, machine learning models often yield inaccurate or biased outcomes. This makes feature engineering tasks, such as feature selection, essential for improving model performance. Various optimization algorithms including the Red Deer Algorithm (RDA), Genetic Algorithm (GA), Particle Swarm Optimization (PSO), and Firefly Algorithm have been employed in early detection of the disease, as documented in the literature. The Red Deer Algorithm (RDA) is an evolutionary optimization method modeled on the social dynamics of red deer herds and has been applied in early disease detection, as documented in the literature (Fathollahi-fard *et al.*, 2020). In this analogy, male deer are termed stags and females hinds. A collection of hinds with several stags constitutes a harem, from which one stag is appointed as the leader. The leader is chosen through roaring contests, with the stag producing the loudest roar taking charge of the harem's management and reproduction. This research seeks to identify Polycystic Ovary Syndrome (PCOS) through the application of the Red Deer Algorithm integrated with machine learning models. The methodology emphasizes extensive hyperparameter optimization using the dataset published by Sreejith *et al.*, (2022) on the Kaggle platform. The decision to employ Support Vector Machine (SVM), K-Nearest Neighbor (KNN), and Extreme Gradient Boost (XGBoost) is supported by prior findings of Avasthi *et al.*, 2024; Rajput *et al.*, 2024 which highlight their robust predictive performance.

The remaining sections of this study is structured as follows: A review of related works in Section 2, the methodology is described in Section 3, the results and discussion are presented in Section 4, and the study is concluded in Section 5.

Related Works

Numerous studies have utilized classical machine learning algorithms in the detection of Polycystic Ovary Syndrome (PCOS), though certain gaps remain. To this end, Inan *et al.*, (2021) sought to apply the XGBoost algorithm for classifying future instances of PCOS data. To examine the performance of seven machine learning models (SVM, KNN, RF, MLP, NB, AdaBoost, and XGBoost) this study employed 540 samples with 41 features that were taken from the Kaggle repository. Results showed that for both PCOS and non-PCOS classifications, XGBoost performed best among all the models used in this study in terms of accuracy, recall, precision, and F-score.

SMOTE and edited nearest neighbor (ENN) were used for data preprocessing. Nonetheless, it was explicitly stated in the study that the dataset size is relatively small which posed a limitation to their research.

Many women of reproductive age suffer from Polycystic Ovary Syndrome (PCOS), a common endocrine condition that causes major problems if untreated or misdiagnosed. To improve PCOS detection, Mou *et al.*, (2023), developed an interpretable machine learning system for diagnostic assistance. Chi-Square, Mutual Information, and Correlation Coefficient were among the several preprocessing techniques and feature selection techniques used in the study. Eight machine learning models (RF, SVM, KNN, LR, Linear Discriminant, CatBoost, LightGBM, and XGBoost) were assessed. A significant drawback, though, was the unequal distribution of PCOS positive versus PCOS negative samples, which might have affected the models' accuracy.

The goal of Rajput *et al.* (2024) was to assess the performance of many classical machine learning methods for PCOS classification using clinical and lab data, including Random Forest, Decision Trees, Artificial Neural Networks, and XGBoost. For feature selection, the study used the Sine Cosine Algorithm to increase efficiency and accuracy. The results indicated that while all classification models did well, XGBoost outperformed the others. Through the identification of the most pertinent features, the incorporation of the Sine Cosine Algorithm significantly increased the accuracy and efficacy of the model. These results highlight how machine learning techniques, especially XGBoost in conjunction with the Sine Cosine Algorithm, have a great deal of promise for improving PCOS detection and categorization in medical contexts. However, a notable limitation lies in the algorithm's complexity, which may hinder scalability and real-world application, especially with very large datasets.

The work of Prapty and Shitu, (2020) detected the presence of PCOS in a patient by developing an efficient decision tree. Four different traditional machine learning models were employed in this study (SVM, RF, KNN and Naïve Bayes) classifiers. A total of 542 dataset with 31 features was obtained from ten different hospitals out of which 177 patients are PCOS positive and 365 patients are PCOS negative. The Principal Component Analysis (PCA) was employed as the feature selection technique in this study. Out of these algorithms Naïve Bayes and Random Forest performed best with accuracies of 93% and 93.5% respectively.

Due to the bad effects of PCOS in women infertility, Thomas and Kavitha, (2020) aim to identify PCOS at an early stage. Doctors from several clinics and hospitals in and around Thodupzha Municipality provided the clinical diagnostic and prescription for this study. The Nguyen-Widrow initialization strategy was adopted in this study as the optimization method. Additionally, MATHLAB R2018a was used as the tool for data mining together with NB, ANN, and a hybrid of the two classifiers. In terms of accuracy (95%), recall, and f-measure, the hybridized classifier fared better than the NB and ANN.

The research by Dutta *et al.*, (2021) aims to identify and detect PCOS using SMOTE and classical machine learning models. A total of 541 items with 14 attributes from the UCI collection was obtained. This study utilized five machine learning models (RF, LR, DT, SVM, and KNN). Principal Component Analysis (PCA) was employed as the feature extraction technique. Standard scalar pre-processing was utilized to prepare the data, and SMOTE was employed as the

optimization method. In terms of accuracy, training time, F1 score, recall, prediction, and area under the ROC, the SMOTE-based LR scored best (97.11%, 0.010 sec., 98%, 98%,98%, and 95.6%).

Several features are used in determining the PCOS status of a female patients to this end, Nandipati *et al.*, (2020) discover which machine learning model is more effective at detecting the PCOS disease, as well as the features that contribute to the disease's prognosis. In this study a dataset with a total of 541 from surveys, doctor consultations, and clinical examinations was taken into account. Eight features were taken from a total of 23 features, which included clinical and metabolic data using SPSS V.2.0. Seven classical machine learning models were employed in this study (KNN, SVM, RF, NB, NN, Bagging and Adaboost) to assess the disease. For Rapidminer's accuracy (93.12%), random forest performed best. The data were pre-processed using Synthetic Minority Oversampling Technique (SMOTE).

Timely detection and management of polycystic ovary syndrome are important to prevent long-term health complications. In lieu to this, Kumar *et al.*, (2024) proposed an approach involving a detailed data preprocessing, feature engineering, and exploratory data analysis (EDA). The preprocessed dataset was employed to classify PCOS cases using several classical machine learning (ML) algorithms, including LR, LDA, GNB, SVM, XGB, DT, AB, RF, and KNN. To further enhance performance, the study integrated these ML algorithms with Particle Swarm Optimization (PSO). Notably, the LR+PSO combination obtained the best accuracy of 96.30%. However, the authors highlighted a potential risk of overfitting, a frequent concern with swarm intelligence methods, where models perform well on training data but fail to generalize effectively to unseen data.

Accurate early prediction is vital to preventing the serious complications often associated with PCOS. To address this, Akanbi *et al.*, (2024) proposed a predictive machine learning (ML) model designed to identify individuals at risk of PCOS and notify healthcare providers for timely intervention. The study employed several ML algorithms, including Random Forest Classifier, Logistic Regression, Gradient Boost, Adaptive Boost, and XGBoost, using a dataset sourced from the Kaggle repository. A noted limitation of the research is the imbalance between PCOS and non-PCOS samples, which may compromise model accuracy.

Chen *et al.*, (2025) employed ensemble machine learning with logistic regression, random forest, and SVM, as well as untargeted lipidomics, to study blood biomarkers for PCOS identification. The study demonstrated that the selected biomarkers offered strong classification performance, with the diagnostic model obtaining an AUC of 0.815, accuracy of 74%, specificity of 88%, and sensitivity of 7%. The low correlation among biomarkers indicated an optimized, nonredundant panel for diagnosis. However, while the ensemble approach improved predictive power, its complexity raised concerns about interpretability and potential overfitting on small datasets.

Emara *et al.*, (2025) proposed a machine learning framework for precise classification of PCOS, integrating stacked learning with ADASYN, SMOTE, and random oversampling to address class imbalance. Feature selection was performed using the BORUTA method to enhance precision and performance. The framework achieved an impressive 97% accuracy in PCOS classification.

However, reliance on multiple feature-selection methods (Chi-Square, PCA, RFE) may introduce selection bias if tuning and evaluation were not properly nested within cross-validation.

Narni *et al.*, (2025) compared decision tree and naïve Bayes models for predicting PCOS using non-invasive clinical features collected from 100 diagnosed cases and 100 controls. Model performance evaluation was assessed based on accuracy, precision, recall, F1 score, and AUC, validated through five-fold cross-validation. While the decision tree showed high training accuracy but overfitting on test data, the naïve Bayes model achieved more stable results with 81% test accuracy and an F1 score of 81%. A key limitation was the small sample size, which may reduce model stability and statistical reliability.

PCOS Detection Model: The Methodology

This section discusses the methods employed for the dataset, the conceptual framework, and algorithmic design utilized in this research using the Red Deer Algorithm for feature selection to effectively detect PCOS owing to the complexity of the dataset based on the SVM, KNN, and XGBoost.

The Proposed PCOS Detection Framework

Figure 1 presents the proposed PCOS detection framework. The framework is premised on the iterative design principles and methodology.

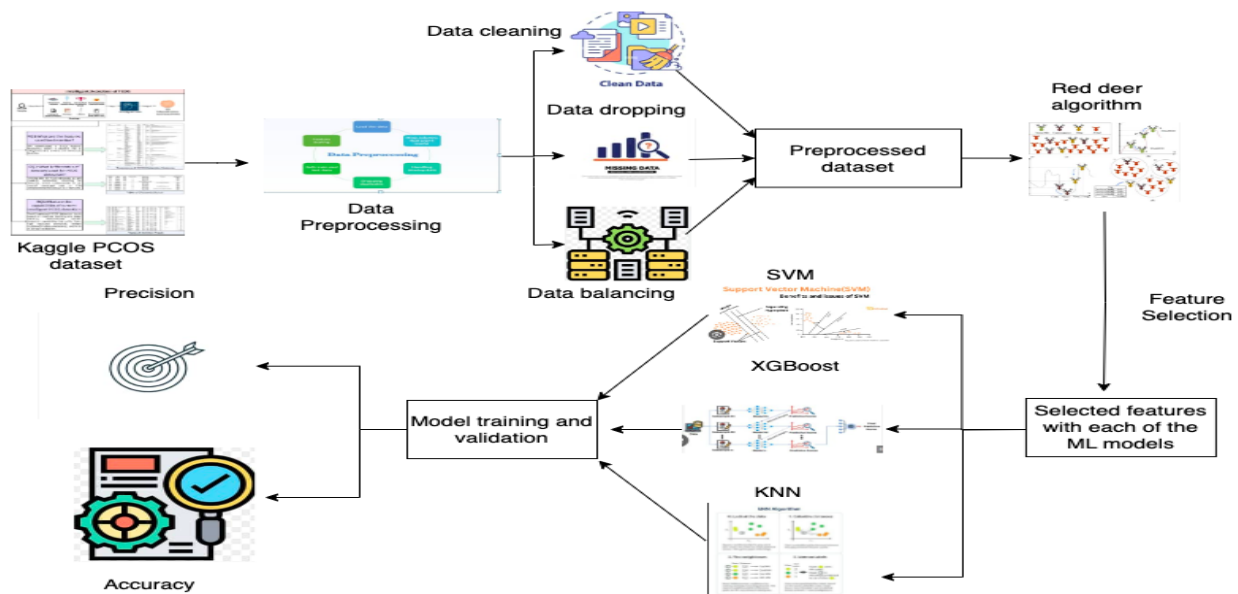


Figure 1: The Proposed PCOS Detection Framework

The proposed advanced optimized PCOS detection framework is shown in Figure 1. The dataset was gathered from the repository on Kaggle. There are 541 data points (data samples) and 45 variables (features) in the PCOS raw dataset. According to data exploration and visualization, the dataset, which is in comma-separated values (CSV) format, includes 364 individuals without PCOS and 177 individuals with the condition. In other words, 364 data points are No and 177 are Yes. The study does, however, show that the dataset is highly unbalance, which could lead to bias in forecasts or seriously reduce overall prediction accuracy. Additionally, while certain features include missing values that are not distributed, most of the features are floating point values. Data preprocessing procedures including scaling, balancing, and data purification are therefore required. The experimental platform for putting this methodology into practice is Python 3.9.0.

The data balancing technique employed in this study is the Synthetic Minority Oversampling Technique (SMOTE). At this phase the dataset has to be balanced before features are selected. With this method, data samples can be generated for the minority class (the "Yes" class). As a result, with 364 samples from each class, both classes would have the same collection of data points. More importantly, the lack of balance across the data classes would make it difficult for the advanced optimizers considered in this study to function correctly.

The data frame was preprocessed using Pandas. Panda was used to load data from the excel spreadsheet. The data cleaning process comprises removing inconsistencies, missing values, and unnecessary information from the dataset, such as patient file number and patient ID, which have no impact on determining PCOS status. Also, the empty cells are tagged '#Name?' this was search for in the dataset and replaced with non- applicable (N/A). It is a panda command. Missing data can be handled by dropping it or by data imputation. The dropping implies that the entire row will be dropped. Likewise, floating point values were used to transform certain features with non-floating values. With widely dispersed floating-point values, this is to guarantee data normalization (scaling) of feature values. For this phase of the study, the Min-Max Scaling (value between 0 and 1) technique is used to better comprehend the model, decrease feature dominance, and increase algorithm performance. Scaling generally helps the machine learning model to work well when the values are within close range.

$$Scaled\_value = (X - Min)/(Max - Min) \quad (1)$$

Where X is the data point's initial value.

Min is the dataset minimal value for each feature.

Max is the dataset maximum feature value.

The preprocessed dataset is then fed into the Red Deer Algorithm for feature selection. The selected features were used for classification with three classical machine learning models (SVM, KNN, and XGBoost). A 70:30 ratio was used for both the model training and validation.

The Red Deer Algorithm (RDA)

Red Deer Algorithm is a nature inspired algorithm that mimics the Red Deer group's behavior. Hinds and a couple stags make up a harem. One of the stags will be chosen to command the harem. To draw in hinds, stags roar loudly, and the one who roars the loudest is usually selected as the leader. The commander is responsible for mating and tending to the harem's hinds. Stag-hind

mating and stag-to-stag competition for commandership continue for generations, ensuring that more red deer with improved fitness are born (sreejith *et al.*, 2022). RDA is an optimization technique proposed by Fathollahi-Fard *et al.*, (2020) based on the roaring mating and fighting behavior of red. The following steps makes up the RDA:

Step 1: Set the initial number of red deer at random.

Step 2: Divide the red deer into stags and hinds based on their fitness category.

Step 3: Stags always fight with their neighbors, and the more fit ones will survive.

Step 4: Based on their level of fitness, choose a commander from the stag population.

Step 5: To produce offspring, mate a commander with a α percentage of hinds in the population.

Step 6: The Commander fights with β percentage of stags in the population.

Step 7: Stop if the new generation of red deer's fitness converges. Otherwise, continue Steps 2 through 6 until a certain number of generations has passed. The Red Deer Algorithm (RDA) is displayed in Table 1.

The basic operation performed by the Red Deer is the roaring, fighting, and mating.

Roaring Equation

$$x_{t+1} = x_t + \alpha_t \alpha \text{randn}() \quad (2)$$

Where:

- $\text{randn}()$ = random vector from standard normal distribution
- α_t is the current step size
- t is iteration at time t
- α is the power operator

Mating Equation

$$x_0 = x_{Sc} + \alpha_t \alpha (x_{Hh} - x_{Sc}) \quad (3)$$

Where

- x_{Sc} is the stag commander
- x_{Hh} is the number of hinds in the Harem
- α_t is the step size at time t
- α is the power operator

Table 1: Algorithmic Representation of the Red Deer Algorithm

Input: t

Output: return D_{aL}

Parameters: PCOS dataset (t), iteration (i), Number of agents (D_a), maximum iteration (M_i), leader_agent (D_{aL}), worst dear fitness (D_{aW}), fitness (f), number of stags (S_d), number of hinds (H_d) stag commanders (S_c), harems (H_h), next generation (N_g)

Procedure:

```

1. Input t
2. Initialize  $D_a$ ,  $D_{aL}$ ,  $D_{aW}$ 
3.  $D_a \rightarrow \text{random\_generator} = \text{random.Random}()$ 
4.  $D_a \rightarrow \text{my\_int} = \text{random.generator.randint}(1, n)$ 
5.  $D_{aL} = 0$ ;  $D_{aW} = 0$ 
6. WHILE  $i \leq M_i$ 
7.     list.sort( $D_a$ ) = f
8.      $S_d, H_d = \text{select.select}(f)$ 
9.      $x_{t+1} = x_t + \vartheta_t \vartheta \text{randn}()$ 
10.     $S_c = \text{select.select}(S_d)$ 
11.    If  $S_c \neq \emptyset$  Then
12.         $H_h$  is formed
13.         $x_0 = x_{Sc} + \vartheta_t \vartheta (x_{Hh} - x_{Sc})$ 
14.        Mating ( $S_c$  with  $H_d$  of another  $H_h$ ) =  $x_0 = x_{Sc} + \vartheta_t \vartheta (x_{Hh} - x_{Sc})$ 
15.        Mating ( $S_d$  with nearest  $H_d$ ) =  $x_0 = x_{Sc} + \vartheta_t \vartheta (x_{Hh} - x_{Sc})$ 
16.         $N_g = \text{select.select}(D_a)$ 
17.    Else GoTo 10
18.    EndIf
19.    Perform standard RDA operations on  $N_g$ 
20.    Update  $D_{aL}$ 
21.    Compute final accuracy for  $D_{aL}$ 
22.    Return  $D_{aL}$ 
23. WEND

```

Table 1 depicts the algorithm for the traditional Red Deer Algorithm. From line 1 input the PCOS textual dataset. Line 2 initialization of the number of agents, leader agent, and worst deer fitness. Line 3 initialization of the number of agents was done randomly. Lines 4 to 5 initialization of the leader agent and worst deer fitness was set to static. Line 6 the while loop was introduced. From lines 7 to 15 the normal deer operation takes place (roaring, fighting, and mating). Line 16 the next generation of deer was selected. From lines 17 to 19 if the condition is satisfied perform the standard RDA operations of the next generation. Else go back to line 10. From lines 20 to 23 update the leader agent, compute the accuracy for the leader agent, return the leader agent and terminate.

Results and Discussion

At this stage, the study is still ongoing; therefore, what has been provided is the conceptual framework upon which the detection model for PCOS disease will be developed. The framework emphasizes the sequential methodological processes, starting with data collection, data preprocessing, and feature selection, and the integration of machine learning algorithms. Numerous researchers have attempted to utilize these models repeatedly for accurate disease detection using the data at available. Nevertheless, variations within the datasets have hindered precision and led to biased performance outcomes.

In the implementation phase, the Red Deer Algorithm will be used for feature selection and three classical machine learning models (SVM, KNN, XGBoost) will be employed to train the models. The dataset was gathered from the repository on Kaggle. There are 541 data points (data samples)

and 45 variables (features) in the PCOS raw dataset. According to data exploration and visualization, the dataset, which is in comma-separated values (CSV) format, includes 364 individuals without PCOS and 177 individuals with the condition. It is important to note that no experimental results are available at this stage of the study. The performance evaluation of the proposed models will only be conducted after implementation, using standard metrics such as accuracy and precision.

Conclusion

The main cause of infertility in women is Polycystic Ovary Syndrome (PCOS), affecting many of them at reproductive age and sometimes continuing long after they reach childbearing age. It is an indisputable fact that there have been ongoing efforts in recent times to utilize different classical machine learning models in early detection of Polycystic Ovary Syndrome. In view of this development, this research aims to detect Polycystic Ovary Syndrome using Red Deer Algorithm (RDA) and Machine Learning models (SVM, KNN, and XGBoost). The Red Deer Algorithm was used for feature selection after which it was combined with each of the models employed in this study.

The PCOS clinical online dataset with 45 features obtained from Kaggle repository was optimized using the RDA and three different machine learning models. The RDA + SVM selected had an accuracy of 88% was achieved. The RDA + RF had an accuracy of 82%. The RDA + XGBoost achieved an accuracy of 86%. In conclusion, based on the performance shown by the Red Deer Algorithm and Firefly Optimization algorithm chances could present itself that if these optimization algorithms are improved on they can perform better. Also, other textual datasets can be considered to increase the generalizability of the research.

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AN OPTIMIZED MACHINE LEARNING APPROACH FOR PREDICTION OF MONKEYPOX DISEASE: THE FRAMEWORK

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Abstract

Monkeypox is a viral zoonotic disease caused by the monkeypox virus (MPXV), part of the Orthopoxvirus genus, which also includes variola (smallpox), vaccinia, and cowpox viruses. The adapted Artificial Bee Colony optimization algorithm is deficient in terms of being sensitive to the tuning parameters. Also, the issue of convergence rate is another challenge associate with the adapted algorithm especially, with complex functions where the search space is huge. Therefore, this research proposes to improve on the algorithm for better performance in terms of accuracy and with machine learning models such as Artificial Neural Network (ANN), Residual Network, and Visual Geometry Group. Therefore, other machine learning models and a dataset from another source can be employed in the prediction of Monkey pox disease to validate the efficiency of the result developed model.

Keywords: Monkeypox Virus (MPXV), Artificial Bee Colony (ABC) Optimizer, Artificial Neural Network (ANN), Residual Network (RESNET), Visual Geometry Group (VGG).

Introduction

Smallpox syndrome, also known as monkeypox, is an uncommon zoonotic viral infection brought on by the monkeypox virus, which belongs to the genus Orthopoxvirus and family Poxviridae (Agustyaningrum *et al.*, 2023). A new viral disease known as Monkey pox has been detected in 75 countries and is currently causing a global outbreak that is spreading quickly (Ekene, 2025). In recent time numerous crises has been faced in the medical sector due to the emergence of previously unknown viral strains and genetic mutations in known viruses. Monkeypox, is a rare disease that has been spreading, particularly in Africa-the main source of the virus-and recently in other regions, particularly the UK and the USA. Detection of monkeypox comes with challenges where symptoms overlapped with other diseases like smallpox, chickenpox, measles, and psoriasis (Saleh *et al.*, 2025). The monkey pox virus, as per the World Health Organization (WHO), describes the reason for uncommon ailment. Being a viral zoonotic ailment, it is easily contacted from animals to humans and among humans as well as the environment (Devarajan *et al.*, 2024).

Monkeypox is a zoonotic disease from the genus Orthopoxvirus that is closely related to cowpox, measles and smallpox in clinical features and belongs to the Poxviridae family (a member of the genus Orthopoxvirus). It is mostly transferred by rodents and monkeys, yet human-to-human spread is rampant (Almutairi, 2022). The disease's main signs are rashes that appear after 3 to 5 days of infection and then appear all over. The body becomes so painful after 3 to 4 weeks that the virus's incubation disappears, and the skin returns to its original shape (Eslam *et al.*, 2024).

In recent years, there has been a dramatic increase in confirmed instances of human monkeypox virus and its geographic expansion as protection to smallpox immunization declines. With a mortality rate of 6%, the 2017 monkey pox epidemic in Nigeria was the worst in the West African

clade (Dahiya *et al.*, 2023). The World Health Organization (WHO) announced that the number of people infected with this virus had increased significantly, and it was confirmed that more than 318,000 patients were infected in August 2022 (Muhammed and Hamdan, 2024). Many applications reap the advance of Artificial Intelligence (AI) and Deep Learning (DL) approaches to ease and facilitate the daily lives of humans. Recently, computer systems based on AI reached accuracy up to par with human experts. Applications of AI are spread over a broad spectrum of fields, such as banking transactions, financial affairs, manufacturing, retail, the supply chain, e-commerce, and healthcare (Khafaga *et al.*, 2022).

Machine learning (ML) is a burgeoning field of AI that has shown great promise in a variety of settings, from decision-making assistance and industrial applications to medical imaging and illness detection. Medical professionals have found that the safe, accurate, and quick imaging solutions made possible by ML are invaluable resources for making informed decisions. There is no doubt that the emergence of artificial intelligence specifically, machine-learning techniques are promising in the area of disease prediction, diagnosis, or detection; however, this is not without gap that can motivate further research. Particularly, the technique has been applied alongside with optimization algorithm in predicting the monkeypox disease owing to its complex nature of the data. In view of this development, Muhammed and Hamdan, (2024) adapted the artificial bee colony optimization algorithm with artificial neural network to predict the monkeypox infection. However, the adapted optimization algorithm is deficient in terms of being sensitive to the tuning parameters. Similarly, the issue of convergence rate is another challenge associate with the adapted algorithm especially, with complex functions where the search space is huge. Therefore, this research proposes to improve on the algorithm for better performance in terms of accuracy and with other ML models.

The remaining sections of this study is structured as follows: A review of related works in Section 2, the methodology is described in Section 3, the results and discussion are presented in Section 4, and the study is concluded in Section 5.

Related Works

The emergence of the monkey pox virus signaled a potential new pandemic. To this end, *Saleh et al.*, 2025 presents a fusion architecture for automatic monkey pox diagnosis by employing a modified grey wolf optimization model for feature selection and weighting. This study employed three machine learning classifiers (NB, LSTM, and Fuzzy logic). However, hybrid pipelines that perform optimization, feature weighting, ensemble classification, and repeated runs require substantial computational resources and this limit the applicability in low-resource or real-time settings.

The study Abdelhamid *et al.*, (2022) of utilized two algorithms for improving the classification accuracy of monkey pox images. These algorithms are based on transfer learning for feature extraction and meta-heuristic optimization for feature selection and optimization of the parameters of a multilayer neural network. The GoogleNet deep network is adopted for feature extraction, and the utilized meta-heuristic optimization algorithms are the Al-Biruni Earth radius algorithm, the sine cosine algorithm, and the particle swarm optimization algorithm. The assessment of the proposed optimization of feature selection for monkey pox classification was performed in terms of ten evaluation criteria. However, this choice GoogleNet for feature extraction and optimized

feature selection by NN parameter limit the potential to exploit more powerful or better-suited architectures such as CNNs or vision transformers that will perform better under certain conditions.

The aim of Alharbi *et al.*, (2023) is to utilize metaheuristic optimization to boost the performance of feature selection and classification methods to identify skin lesions as indicators of monkey pox. The GoogLeNet network is the deep learning framework employed for feature extraction. Also, a binary implementation of the dipper throated optimization (DTO) algorithm is used for feature selection. The decision tree classifier is then used to label the selected set of features. However, the pipeline relies on the quality of the transfer learning feature extractor (GoogLeNet in this case) and on feature selection (via the binary DTO) which helps in reducing dimensionality, the approach losses some useful features or patterns.

Alnaji, (2024) integrates advanced machine learning techniques, (Artificial Neural Networks, Long Short-Term Memory, and Gated Recurrent Unit models), to forecast monkeypox outbreaks in Canada, Spain, the USA, and Portugal. This study identifies optimal model configurations and underscores the efficiency of the Levenberg-Marquardt algorithm in training. The findings suggest that ANN models, particularly those with optimized Root Mean Squared Error, Mean Absolute Percentage Error, and the Coefficient of Determination values, are effective in infectious disease forecasting and can significantly enhance public health responses. However, neural networks (ANN, LSTM, GRU) with many parameters are used, there is a risk the models overfit to the training data, and thus perform worse on new or unseen scenarios.

The growing monkeypox epidemic has been classified as a “public health emergency of international concern” (PHEIC) by the World Health Organization (WHO). To this end, Dada *et al.*, (2022) proposes stacking ensemble learning and machine learning techniques to forecast the rate of transmission of monkey pox. This study employed adaptive boosting regression (Adaboost), gradient boosting regression (GBOOST), random forest regression (RFR), ordinary least square regression (OLS), least absolute shrinkage selection operator regression (LASSO), and ridge regression (RIDGE) were applied for time series forecasting of monkey pox transmission. However, the monkeypox dataset used for testing was relatively small which limits how well the testing reflects full range of variability in monkeypox outbreaks.

The availability of Monkey pox dataset motivated the study of Eid *et al.*, (2022) to propose a new approach for accurate prediction of the Monkey pox confirmed cases based on an optimized Long Short-Term Memory (LSTM) deep network. In order to fine-tune the hyper-parameters of the LSTM-based deep network, the Al-Biruni Earth Radius (BER) optimization algorithm was employed. Six machine learning techniques were utilized in the conducted experiments. In addition, four different optimization algorithms are considered for comparison purposes. However, it was implicitly stated that the approached employed in this study can be generalized and tested for other datasets. Which implies that the researchers are yet to validated the method broadly across diverse geographies, disease outbreaks, or variant data regimes. Thus, external generalizability is still unproven.

Accurately diagnosing monkey pox based on visual inspection of the lesions can be challenging and time-consuming. To this end, Eliwa *et al.*, (2023) proposes an approach using CNNs to classify

monkey pox skin lesions. Additionally, the study optimized the CNN model using the Grey Wolf Optimizer (GWO) algorithm, resulting in a significant improvement in accuracy, precision, recall, F1-score, and AUC compared to the nonoptimized model. However, it was implicitly stated that there is *limited availability of large and high-quality datasets of monkeypox skin lesions*, which restricts the ability to train and validate CNNs robustly.

Monkey Pox Detection Model: The Methodology

This section discusses the methods employed for the dataset, the conceptual framework, and algorithmic design utilized in this research using the Enhanced Adapted ABC Optimizer to effectively detect MPXV based on the ANN, RESNET and VGG.

The Proposed MPXV Detection Framework

Figure 1 presents the proposed MPXV detection framework. The framework is premised on the iterative design principles and methodology.

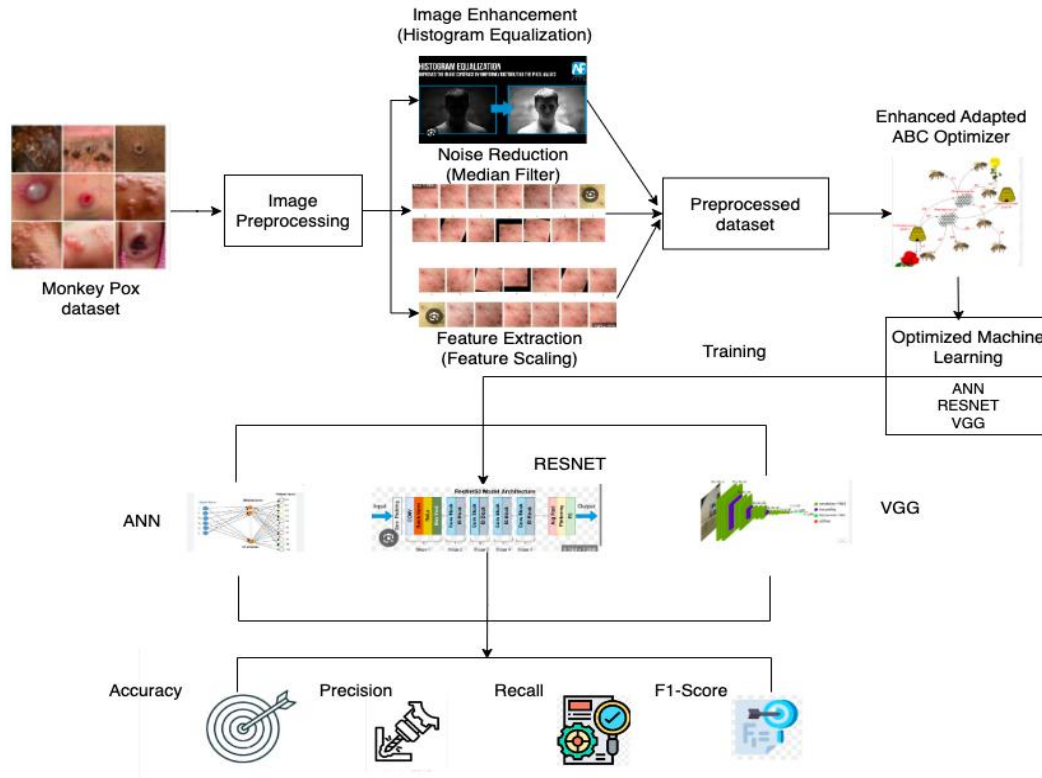


Figure 1: The Proposed MPXV Detection Framework

This study is a multi-stage strategies that ranges from the obtained of the monkey pox dataset to the evaluation of the results. The Monkey pox dataset was obtained from the Kaggle repository with a total of 3420 images. Different image preprocessing techniques were applied on the images obtained. Histogram equalization was applied on the images for enhancing the images dataset. Median filter technique was applied on the images to reduce noise from the images. Feature scaling was done by extracting the relevant features on the images. The preprocessed images dataset is

then fed into the enhanced adapted artificial bee colony optimizer where feature selection takes place after which the machine learning models (ANN, RESNET, VGG) will be used to train and test the selected features based on accuracy, precision, recall, and F1-score. The algorithmic representation is depicted by Table 1.

Table 1: Algorithmic Representation of the Monkey Pox Predictive Model

<i>Input: d</i>	
<i>Output: M*, θ^*, Metrics</i>	
<i>Parameters: Monkey pox dataset (d) ABCOptimization Algorithm (P) , Histogram Equalization (H_e) Median Filter(M_f), Feature Scaling (F_s), Candidate solution in the search space(θ), Model (M)</i>	
1.	Input d
2.	Preprocess d (H_e , M_f , F_s)
3.	Initialize population P //hyperparameter setting
4.	For cycle = 1 to params.max_cycles do
5.	For each solution θ in P do
6.	Train M(θ) on Train
7.	fitness(θ) = Eval(M(θ), Val)
8.	Update θ using employed bee rule
9.	End for
10.	Select solutions based on fitness
11.	Update poorly performing solutions
12.	End for
13.	$\theta^* = \operatorname{argmax} \text{fitness}(\theta)$
14.	$M^* = \text{Train}(M, \theta^*, \text{Train} + \text{Val})$
15.	Metrics = Eval(M^* , Test)
16.	Return M^* , θ^* , Metrics

Table 1 depicts the algorithmic representation of the Monkey pox prediction model. At line 1 the monkey pox dataset is loaded. at line 2 the preprocessing of the monkey pox image data set is done by employing histogram equalization for contrast, median filter for noise reduction and feature scaling for the extraction of features. At line 3 the randomly generated initial hyperparameter is set by initializing population p. At line 4 the optimization loop is commenced and this is repeated until the maximum number of cycle is achieved. At line 5 there is a loop through each of the hyperparameter set. At line 6 it instantiate the model M with hyperparameters θ and trains it on a portion of data. At line 7 the trained model is evaluated on the validation set. At line 8 the exploration of neighbors takes place and it keep update if performance improves. At line 9 it finishes evaluating all candidate solutions in the population. At line 10 the bees choose food source (θ) based on probability proportional to fitness with a promising solution to get more attention. At line 11 scout bees replace weak solutions with new random θ . At line 12 the optimization loop is completed. At line 13 the best-performing hyper parameter configuration among all explored solutions is selected. At line 14 it retrain the model from scratch using θ^* on the combined Train+Val set for maximum learning. At line 15 evaluation of M^* on the unseen test set to estimate

true performance. At line 16 the optimized model, its hyper parameters, and test evaluation metrics is output.

Results and Discussion

At this stage, the present study is still ongoing; therefore, what has been provided is the conceptual framework upon which the predictive model for monkeypox disease will be developed. The framework emphasizes the sequential methodological processes, beginning with data preprocessing and image preparation, followed by feature extraction and the integration of machine learning algorithms. The objective is to develop a model to improve the artificial bee colony algorithm for the proposed prediction model to predict monkeypox disease.

In the implementation phase, Artificial Neural Networks (ANN) and Convolutional Neural Networks (CNN) will be applied for model training. The ANN will serve as a baseline machine learning technique for handling structured input features, while the CNN will be particularly important for image-related datasets due to its superior capability in automatically learning hierarchical features from raw images. A total of about three thousand one hundred and ninety-five (3,195) monkeypox dataset sourced from kaggle repository will be used in this phase. It is important to note that no experimental results are available at this stage. The performance evaluation of the proposed models will only be conducted after implementation, using standard metrics such as accuracy, precision, recall, and the F1-score.

Conclusion

The aim of this research is to develop a predictive framework that enhances the Artificial Bee Colony (ABC) algorithm for improved prediction of monkey pox disease. The study has outlined a conceptual model that incorporates an enhanced adapted ABC algorithm with machine learning methods such as Artificial Neural Networks (ANNs) and Convolutional Neural Networks (CNNs). The improved algorithm is intended to overcome existing drawbacks of the standard ABC, particularly its dependence on parameter sensitivity and its tendency toward slow convergence. While experimental implementation is still in progress, the framework demonstrates a clear methodological pathway that integrates preprocessing, image analysis, and advanced learning models. Upon completion, the optimized ABC based model is expected to achieve better outcomes across evaluation metrics such as accuracy, precision, recall, and F1-score. More so, this approach has the potential to enhance early detection strategies and support proactive public health responses to monkey pox and other emerging infectious diseases.

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INNOVATIVE LEARNING ACTIVITIES AND TECHNIQUES OF THINKING-BASED LEARNING MODULE FOR EMPOWERING FABRICATION AND WELDING CRAFTSMEN WITH 21ST CENTURY EMPLOYMENT SKILLS IN NORTH-WEST NIGERIA

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Abstract

This study developed innovative learning activities and techniques of a thinking-based learning module aimed for empowering Fabrication and Welding Craftsmen with 21st-century employability skill in North-West Nigeria. The study was guided by two research questions and two null hypotheses. The study employed descriptive survey research design. The study involved 822 participants, including school-based and industry-based subject matter experts, as well as craftsmen. The instrument used was a structured questionnaire titled “Fabrication and Welding Craftsmen Thinking-Based Learning Module Questionnaire (FWCTBLMQ)”. The instrument was subjected to face and content validation by three experts. The reliability of FWCTBLMQ was found to be 0.83 through Cronbach Alpha statistics. Data analysis using mean, standard deviation, z-test, and ANCOVA revealed key learning activities within the module, such as answering open-ended questions during reading (mean = 4.58), applying structured problem-solving frameworks (mean = 4.56), engaging with real-world scenarios (mean = 4.38), and peer teaching (mean = 4.52). Effective learning techniques identified included active reading (mean = 3.52), project-based learning (mean = 4.42), use of e-books (mean = 4.63), and hands-on activities (mean = 4.52). The study recommended that fabrication and welding instructors integrate these activities and techniques into their teaching to boost instructional effectiveness and better prepare craftsmen for the workforce. Additionally, the study recommended that the National Board for Technical Education (NBTE) should facilitate professional development workshops and seminars to promote adoption of the module’s strategies among educators and trainers in the field.

Keywords: Development, Thinking-Based Learning Module, 21st century, Employability Skills, Fabrication and Welding.

Introduction

Fabrication and welding, as taught in Nigeria’s technical colleges, aims to produce skilled craftsmen competent in the safe use of equipment, materials, and techniques for metal fabrication projects (FRN, 2013; NBTE, 2008). Graduates should be able to perform gas welding and cutting on various metals and produce structural steel work to standard. However, many graduates lack the 21st-century employability skills necessary for effective job placement (FGN, 2022). The modern economy demands rapid adaptation to changing job requirements, especially as technological advancements reshape skills needs. Countries worldwide invest in education and

training to enhance employability, with thinking-based learning (TBL) identified as a promising approach (Swartz & McGuinness, 2014). TBL is an instructional strategy designed to develop critical and creative thinking in learners. It uses structured routines, guided steps, and active learner participation to improve reasoning, problem-solving, and decision-making abilities (Kalelioglu et al., 2016; Ghor, 2021). This pedagogy also supports the acquisition of 21st-century employability skills, which include critical thinking, creativity, collaboration, and communication—commonly referred to as the “4Cs” (AMA, 2010; Pirzada, 2020). These skills are transferable, relevant across industries, and essential for career success, mobility, and adaptability (Rasul *et al.*, 2010; Stauffer, 2022).

A learning module is a structured set of activities and materials designed to achieve specific objectives which can serve as a vehicle for delivering these skills. Effective modules include objectives, content, learning techniques, resources, and assessment strategies (Atha, 2021). Learning activities within the module are not mere tasks; they are intentional, structured experiences that foster engagement, provide feedback, and promote retention (Biggs & Tang, 2011; Freeman *et al.*, 2014). Learning techniques refer to methods or strategies, such as active learning, spaced repetition, and self-testing, that promote knowledge acquisition and application (Persaud, 2021; Akdeniz, 2018). Integrated effectively, these techniques can enhance employability skills and support self-directed learning.

Problem Statement:

Despite the aims of Nigeria’s fabrication and welding programme, many graduates lack the critical employability skills demanded by industry. As a result, up to 80% struggle to secure sustainable employment, contributing to the high unemployment and underemployment affecting over 65 million Nigerians. This skills–industry mismatch underscores the need for a self-instructional TBL module tailored to the employability needs of fabrication and welding craftsmen in North-West Nigeria.

Aim and Objectives:

The study aim of the study was to develop a TBL module that strengthens the 21st-century employability skills of fabrication and welding craftsmen. Specifically, the study sought to:

1. Identify the learning activities of thinking-based module.
2. Identify the learning techniques of the thinking-based module.

Research Questions

The following research questions guided the study:

1. What are the learning activities of the thinking-based module for enhancing 21st-century employability skills among fabrication and welding craftsmen?
2. What are the learning techniques of the thinking-based learning module for enhancing 21st-century employability skills among fabrication and welding craftsmen?

Hypotheses: The following null hypotheses were formulated to guide the study and tested at the 0.05 level of significance:

1. There is no significant difference between the mean responses of school-based and industry-based subject matter experts on the learning activities of the thinking-based module for enhancing 21st-century employability skills among fabrication and welding craftsmen.

2. There is no significant difference between the mean responses of school-based and industry-based subject matter experts on the learning techniques of the thinking-based learning module for enhancing 21st-century employability skills among fabrication and welding craftsmen.

Methodology The study adopted a mixed-methods research design involving survey, interview, and quasi-experimental approaches. According to Guetterman *etal.*(2017), combining these methods is valuable for exploring complex phenomena and establishing causal relationships. Two research questions guided this study, and two hypotheses were tested at a 0.05 level of significance. The study was conducted in the North-West region of Nigeria—one of six geopolitical zones—comprising seven states. The target population consisted of 822 respondents: 201 school-based subject matter experts, 337 industry-based subject matter experts, and 284 fabrication and welding craftsmen. Simple random sampling was used for both the quantitative respondents and the three qualitative interviewees. Six instruments were developed for data collection, including the Fabrication and Welding Craftsmen Thinking-Based Learning Module Questionnaire (FWCTBLMQ) and Interview Protocol (FWCTBLMIP), both face-validated by three experts. Reliability was established via pilot testing in Niger State with 12 randomly selected SMEs. FWCTBLMQ yielded a Cronbach's alpha of $\alpha = 0.83$; FWCTBLMIP a Cohen's kappa of 0.81; and FWCESAT a KR-20 coefficient of 0.84. Data were analyzed using SPSSv27: means to answer research questions, standard deviations to measure score dispersion, and z-tests to examine hypotheses at the 0.05 significance level

Research Question One

What are the Learning Activities of the Thinking-based Learning Module for enhancing 21st Century Employability Skills among Fabrication and Welding Craftsmen?

The data for answering research question one is presented in Table 1.

Table 1: Mean and Standard Responses of Respondents on the Learning Activities of the Thinking-based Learning Module

S/N	Items	Mean ($\bar{x}$) N = 329	SD	Remark
Reading assignments:				
1	Provide a set of open-ended questions that must be answered as reading goes on.	4.58	0.65	SA
2	Have a journal where reflection on reading experiences are documented	4.53	0.50	SA
3	Create checklists to evaluate understanding of key concepts	4.29	0.65	A
4	Create visual representations of the main ideas from reading	4.52	0.38	SA
5	Write a concise summary of the main ideas after reading	4.55	0.74	SA
6	Create mind maps to visually organize the main ideas from the reading	4.48	0.55	A
7	Generate questions about the reading that require deeper thinking	4.50	0.64	SA
8	Create an annotated bibliography of the reading	3.94	0.70	A
9	Design a creative project that represents the understanding of the reading	4.18	0.61	A
10	Set specific learning goals related to the content and outline steps to achieve them	4.30	0.80	A

11	Choose a topic related to the reading and conducting independent research	4.22	0.68	A
	Problem-solving exercises:			
12	Analyze real-world case related to the content to identify key issues	4.59	0.71	SA
13	Select current issue in the field of study and outline its significance	4.46	0.69	A
14	Brainstorm multiple potential solutions	4.30	0.50	A
15	Assume different roles related to the problem	3.22	0.60	D
16	Conduct root cause analysis to determine underlying issues	4.65	0.52	SA
17	Apply specific problem-solving framework to develop a structured solution	4.56	0.48	SA
18	Engaging in design thinking process to define the problem	3.17	0.50	D
19	Create a detailed action plan to address the specific problem	4.62	0.70	SA
20	Reflecting on a personal experience related to the problem	3.40	0.44	D
21	Consider diverse perspectives in finding solutions	4.72	0.60	SA
22	Present the proposed solutions to peers for feedback	4.55	0.54	SA
23	Design a project that addresses local issue	4.48	0.80	A
	Interactive quizzes:			
24	Create quizzes with multiple-choice questions	4.40	0.64	A
25	Develop series of true/false statements related to the content	4.30	0.66	A
26	Present real-world scenarios related to the module	4.38	0.68	A
27	Create fill-in-the-blank quizzes	4.20	0.80	A
28	Develop matching quizzes	4.54	0.60	SA
29	Use online polling tools to conduct live polls	4.46	0.79	A
30	Create digital flashcards for key concepts and terms	4.40	0.52	A
31	Organize a Jeopardy-style quiz game	4.48	0.48	A
32	Create quiz questions based on the content	4.55	0.70	SA
	Concept mapping:			
33	Create a basic concept map that outlines the main ideas from a specific topic	4.56	0.59	SA
34	Develop a hierarchical concept map that organizes concepts from general to specific	4.10	0.69	A
35	Create a collaborative concept map on a shared topic	4.68	0.91	SA
36	Use digital tools to create interactive concept maps	4.55	0.70	SA
37	Revisit initial concept maps and revise them based on new knowledge	3.38	0.81	D
38	Create a concept map that connects concepts with ideas from other disciplines	4.54	0.70	SA
39	Develop concept map that outlines a specific problem	3.40	0.55	D
40	Create a concept map that includes questions related to each concept	4.20	0.64	A
	Mind mapping exercises:			
41	Create a mind map that outlines the main concepts of a specific topic	4.58	0.68	SA
42	Develop a mind map that highlights key concepts, definitions, and examples	4.08	0.78	A
43	Create a mind map that connects the content to personal experiences	4.19	0.68	A
44	Create a mind map on a shared topic	4.28	0.64	A
45	Create interactive mind maps that can be easily edited or shared	4.18	0.70	A
46	Develop a mind map that outlines specific problems and potential solutions	4.21	0.61	A
47	Create a mind map that compares and contrasts two or more concepts	4.56	0.80	SA
48	Create a mind map that reflects on what have been learnt	4.58	0.68	SA
49	Use a mind map to plan a project related to the module	4.68	0.50	SA
50	Create a mind map that serves as a study guide for an upcoming assessment	4.55	0.70	SA
51	Develop a mind map that explores how the concepts learned	4.19	0.69	A
	Experiential learning tasks:			
52	Conduct field research related to the content	4.39	0.60	A

53	Create simulations that mimic real-world scenarios	4.10	0.52	A
54	Document the experiences and insights gained from the activities	3.39	0.48	D
55	Analyse real-life case studies to identify problems, evaluate solutions and discuss outcomes	4.18	0.50	A
56	Engage in hands-on activities related to the content	4.62	0.64	SA
57	Prepare lesson on a specific topic and teach peers	4.52	0.70	SA
58	Conduct a project that addresses a real-world problem or challenge	4.45	0.70	A
59	Conduct interviews with professionals in the field	4.10	0.61	A
60	Embark on field trips to relevant sites	4.64	0.80	SA
Gamified learning activities:				
61	Create competitive quizzes using online platforms	3.92	0.40	A
62	Design an escape room-style activity for solving puzzles and complex tasks	4.52	0.65	SA
63	Award digital badges for completing specific tasks or mastering concepts	4.65	0.69	SA
64	Implement a leaderboard that tracks progress and achievements	3.20	0.50	D
65	Organize a scavenger hunt to search for information or complete tasks	4.19	0.60	A
66	Use simulation software or online platforms to engage in realistic scenarios	4.10	0.85	A
67	Use flashcard apps to create games for answering questions correctly and quickly.	4.16	0.75	A
68	Use story cubes or dice with images related to the content	4.32	0.55	A
Data analysis exercises:				
69	Gather data from various sources	4.52	0.88	SA
70	Prepare the data for analysis by cleaning it.	4.57	0.74	SA
71	Conduct exploratory data analysis	4.45	0.66	A
72	Identify the most relevant features for analysis	4.18	0.77	A
73	Select the most relevant features for analysis	4.61	0.58	SA
74	Select appropriate statistical based on the problem type	4.50	0.60	SA
75	Implement the chosen analysis method using the prepared data	3.48	0.76	D
76	Analyze the output of the analysis to draw meaningful conclusions	4.10	0.80	A
77	Present the results in a clear and concise manner	3.94	0.79	A
Podcast listening activities:				
78	Take notes on key points, insights, and interesting quotes	4.30	0.72	A
79	Form a small group with friends or colleagues to discuss episodes after listening	4.22	0.85	A
80	write a reflection on what you learned	3.94	0.75	A
81	Write a brief summary of the episode	4.18	0.55	A
82	Identify actionable insights from the episode	4.30	0.68	A
83	Set a goal to listen to a certain number of episodes within a specific timeframe	4.18	0.64	A
84	Create a podcast playlist	4.48	0.70	A
85	Create a bingo card with common themes or phrases	4.54	0.61	SA
Virtual simulations:				
86	Use virtual reality or computer-based simulations to practice	4.52	0.68	SA
87	Engage in flight simulation activities	4.38	0.70	A
88	Use software to simulate engineering processes	4.50	0.70	SA
89	Engage in virtual reality simulations that focus on developing soft skills	3.46	0.69	D
90	Participate in simulations that mimic soft skills improvement	4.18	0.50	A
91	Use role-playing simulations to practice	4.32	0.60	A
Grand Mean/SD		4.28	0.65	Agreed

Key: N = Number of respondents; SD = Standard Deviation; SA = Strongly Agree; A = Agree

Analysis of Table 1

The analysis presented in Table 1.1 highlights the mean responses of participants regarding the learning activities embedded in the thinking-based learning module for enhancing 21st-century employability skills among fabrication and welding craftsmen. The computed mean scores range from 3.17 to 4.72, resulting in an overall grand mean of 4.28. This grand mean indicates that the respondents collectively agreed that all the listed items represent relevant learning activities for the module. The standard deviation values range between 0.38 and 0.91, with an average of 0.65. This relatively low average standard deviation suggests a high degree of consistency in the respondents' views, demonstrating that their responses were closely aligned. Such closeness enhances the reliability of the mean values obtained. Based on these findings, it is concluded that all the items identified are valid and agreed upon as the learning activities of the thinking-based learning module, underscoring their potential effectiveness in fostering essential employability skills for craftsmen in the fabrication and welding field.

Research Question Two

What are the Learning Techniques of the Thinking-based Learning Module for enhancing 21st Century Employability Skills among Fabrication and Welding Craftsmen?

The data for answering research question two is presented in Table 2.

Table 2: Mean and Standard Responses of Respondents on the Learning Techniques of Thinking-based Learning Module

S/N	Items	Mean ($\bar{x}$) N = 329	SD	Remark
1	Active reading	3.52	0.50	A
2	Spaced repetition	3.05	0.70	D
3	Role-playing	2.44	0.44	SD
4	Case studies	3.14	0.60	D
5	Experiential learning	4.10	0.54	A
6	Project-based learning	4.42	0.84	A
7	Problem-based learning	4.51	0.40	SA
8	Collaborative learning	2.70	0.64	D
9	Scenario-based learning	2.90	0.66	D
10	Reflective learning	3.50	0.68	A
11	Peer learning	3.10	0.80	D
12	Gamification	3.60	0.60	A
13	Discussion	3.88	0.79	A
14	Mind mapping	4.23	0.52	A
15	Brainstorming	4.09	0.48	A
16	Design thinking	4.12	0.70	A
17	Auditory learning	3.09	0.60	D
18	Field trips	3.40	0.70	D
19	Inquiry-based learning	3.60	0.50	A
20	Simulations	4.40	0.69	A
21	Hands-on activities	4.52	0.50	A
22	Research projects	3.29	0.60	D
Grand Mean/SD		3.61	0.62	Agreed

Key: N = Number of respondents; SD = Standard Deviation; SA = Strongly Agree; A = Agree

Analysis of Table 2

The analysis presented in Table 2.1 outlines the mean responses of participants to the 22 items designed to identify the learning techniques of the thinking-based learning module for enhancing 21st-century employability skills among fabrication and welding craftsmen. The mean values ranged from 2.44 to 4.51, with an overall grand mean of 3.61. This indicates that respondents agreed with most of the items as relevant learning techniques for the module. The standard deviation values varied from 0.48 to 0.84, yielding an average of 0.62. This relatively small spread demonstrates that respondents' views were closely aligned, reflecting consistency and enhancing the reliability of the calculated means. Consequently, these results affirm that the identified items are appropriate and widely accepted as learning techniques capable of supporting the development of essential employability skills among fabrication and welding craftsmen.

Hypothesis One

The result of hypothesis one which states that there is no significant difference between the mean responses of school-based and industrial-based subject matter experts on the learning activities of the thinking-based module for enhancing 21st century employability skills among fabrication and welding craftsmen is presented in Table 3.

Table 3: Z-Test Analysis Showing the Result of Hypothesis on the Learning Activities of the Module

		Levene's Test for Equality of Variances		z-test for Equality of Means						95% Confidence Interval of the Difference	
		F	Sig.	Z	df	Sig. (2- tailed)	Mean Diff.	Std. Error Diff.		Lower	Upper
Learning Activities	Equal variances assumed	7.28	0.13	4.37	327	0.65	.1724	.0705		-.363	.148
	Equal variances not assumed			3.80	34.70	.045	.1724	.0701		-.333	.118

($p > 0.05$) NS = Not significant

Table 3 presents the z-test results comparing the mean responses of school-based and industrial-based SMEs on the learning activities of the thinking-based learning module for enhancing 21st-century employability skills among fabrication and welding craftsmen. Levene's test for equality of variance produced an F-value of 7.28 with a p-value of 0.13. As the p-value exceeds the 0.05 threshold, the assumption of equal variances was retained. The z-test yielded a value of 4.37 with an associated p-value of 0.65, also greater than the 0.05 benchmark. This indicates that the observed differences in mean responses between the two groups were not statistically significant. Consequently, the third null hypothesis was upheld, confirming that school-based and industrial-based SMEs held comparable views regarding the identified learning activities within the module.

Hypothesis Two

The result of hypothesis two which states that there is no significant difference between the mean responses of school-based and industrial-based subject matter experts regarding the learning techniques of the thinking-based learning module for enhancing 21st century employability skills among fabrication and welding craftsmen is presented in Table 4.

Table 4: Z-Test Analysis Showing the Result of Hypothesis on the Learning Techniques of the Module

		Levene's Test for Equality of Variances				z-test for Equality of Means				
		F	Sig.	z	df	Sig. (2- tailed)	Mean Diff.	Std. Error Diff.	95% Confidence Interval of the Difference	
									Lower	Upper
Learning Techniques	Equal variances assumed	2.78	0.42	1.71	327	0.02	4.20	0.71	-.082	2.32
	Equal variances not assumed			1.08	21.14	0.04	3.86	0.68	-.079	2.28

($p < 0.05$) S = Significant

Table 4 presents the z-test results assessing whether a significant difference exists between the mean responses of school-based and industrial-based SMEs regarding the learning techniques of the thinking-based learning module for enhancing 21st-century employability skills among fabrication and welding craftsmen. Levene's test for equality of variance returned an F-value of 2.78 with a p-value of 0.42. Since this p-value exceeds the 0.05 threshold, the assumption of equal variances was maintained. The z-test analysis yielded a calculated value of 1.71 with an associated p-value of 0.02, which is below the 0.05 level of significance. This result indicates that there is a statistically significant difference between the mean responses of the two groups. Consequently, the fourth null hypothesis was rejected, confirming that school-based and industrial-based SMEs differed significantly in their perceptions of the learning techniques incorporated in the module.

Findings of the Study

Based on the data collected and analyzed, the following findings emerged:

1. The learning activities of the innovative thinking-based learning module for enhancing 21st-century employability skills among fabrication and welding craftsmen include problem-solving exercises, experiential learning tasks, mind-mapping exercises, reading assignments, dialectical thinking exercises, and root cause analysis, among others. Analysis of hypothesis three revealed no significant difference between the mean responses of school-based and industrial-based SMEs regarding these learning activities.
2. The learning techniques of the innovative thinking-based learning module for enhancing 21st-century employability skills among fabrication and welding craftsmen include hands-on learning, project-based learning, inquiry-based learning, and problem-based learning, among

others. Analysis of hypothesis four revealed a significant difference between the mean responses of school-based and industrial-based SMEs regarding these learning techniques.

Discussion of Findings

The findings, discussed in line with the research questions and hypotheses, show that the identified learning activities—such as problem-solving exercises, experiential learning tasks, mind-mapping, reading assignments, dialectical thinking, and root cause analysis—were supported by both quantitative and qualitative data. Ninety-one items, grouped into ten clusters, were validated as appropriate learning activities. Qualitative input from SMEs reinforced these results, indicating consensus across groups. This alignment suggests that these activities are critical to making the thinking-based module effective for enhancing employability skills.

These results align with prior studies, including Putri *et.al.*(2023), who identified active reading, problem-solving, experiential tasks, and hands-on activities as core to project-based learning modules that develop critical thinking. They also correspond with Heong *et.al.* (2020) and Tajudin *et.al.* (2019), who listed similar activities—interactive quizzes, gamified tasks, and dialectical thinking. The statistical result of hypothesis three, consistent with Nazifah and Asrizal (2022), confirmed no significant difference between school-based and industry-based SMEs, further validating the relevance of the 91 identified activities. Regarding learning techniques, nineteen were identified, including hands-on, project-based, inquiry-based, and problem-based learning, as well as active reading, brainstorming, collaborative work, and experiential learning. Here, SMEs' qualitative responses matched the quantitative data, though differences emerged between the two groups, as indicated by the rejection of hypothesis four. This variation may stem from differing perspectives and experiences in applying these techniques in educational versus industrial contexts.

These results correspond with Desti and Razak (2023), who highlighted active reading, simulations, project-based learning, and gamification as effective techniques for improving critical thinking; and with Susilawati *et.al.* (2021), who identified peer learning, brainstorming, and inquiry-based learning as effective for creative skill development. They also align with Tajudin *et.al.* (2019) regarding core hands-on and problem-based approaches. However, unlike Puput *et.al.* (2020), who found no significant difference between teachers and students, this study revealed a marked difference between SMEs, possibly due to their varying exposure to pedagogical practice and workplace skill demands. The qualitative data from SMEs offered additional validation for both the learning activities and techniques, reinforcing the module's relevance for developing 21st-century employability skills among fabrication and welding craftsmen.

Conclusion

The study successfully identified the key components necessary for developing an effective learning module to enhance 21st-century employability skills among fabrication and welding craftsmen. The findings revealed **clearly defined objectives, relevant content, appropriate learning activities, effective learning techniques, self-learning facilities, and self-assessment strategies** as essential elements for the design of a thinking-based learning module. These components informed the development of a module tailored to enhance critical skills such as **creative thinking, effective communication, collaboration, emotional intelligence, and time management**. This dual emphasis on technical proficiency and cognitive/metacognitive

competence ensures that craftsmen are equipped to meet the demands of a modern, dynamic workforce. Through addressing identified skill gaps in the fabrication and welding sector in North-West Nigeria, the module represents a significant step toward improving productivity and professional standards. Empirical testing demonstrated the module's effectiveness in enhancing 21st-century employability skills. When applied judiciously, it has the potential to strengthen craftsmanship, boost employability, and improve overall workforce performance in the sector. Accordingly, the study concludes that the developed innovative thinking-based learning module is a viable, impactful tool for advancing the employability skills of fabrication and welding craftsmen in North-West Nigeria.

Recommendations

Based on the study's findings, the following recommendations are proposed:

1. Fabrication and welding instructors should adopt the recommended learning activities from the thinking-based learning module within their teaching methodologies to enhance instructional effectiveness and ensure craftsmen acquire the essential skills for career success.
2. The National Board for Technical Education (NBTE) should organize targeted professional development workshops and seminars on the learning techniques highlighted in the module. These training sessions, aimed at educators and trainers in welding and fabrication, would help align teaching practices with industry expectations and better prepare craftsmen for the workforce.

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ARTIFICIAL INTELLIGENCE, TEACHER EDUCATION AND PROFESSIONAL DEVELOPMENT IN THE 21ST CENTURY

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Abstract

The importance of teacher education and professional development cannot be overemphasized. Artificial Intelligence (AI) is rapidly transforming education globally with significant implication for teacher training and professional development. As an emerging technology, it provide tools for enhancing personal learning, data-driven decision –making, teaching, learning and research. In teacher education, AI integration can support pre-service and in service teacher through digital tools to improve instructional delivery. This paper x-rays teacher education, and its stages. The paper considers career development as a means of equipping teachers with digital skills, fostering professional growth, and preparing educators to meet the demands of technology-driven labor market. However, Issues such as insufficient funding, inadequate infrastructure, limited digital literacy and poor regulatory frameworks makes teachers vulnerable to job displacement and skill mismatch. The paper highlights the need for proactive solutions to address these issues such as investing heavily in education and skill development, encouraging entrepreneurship and innovation and social protection and safety nets.

Keywords: Artificial intelligence, Teacher education Career development

Introduction

The rate at which technological advancements are taking place in the 21st century could best be described as unprecedented. Nowadays, computers and smartphones are owned by individuals, teachers and students to enable them upload, retrieved and disseminate information. Today machines are gradually dominating and accelerating the phase of problem solving. The 21st century marked a breakthrough in the sophistication of Artificial Intelligence (AI). AI is no longer incorporated in computer design and study, but a separate new field. In recent times, AI has gain far reaching popularity and usage in education, teaching and research. Artificial Intelligence is a term used to describe a machines' ability to simulate human intelligence. Artificial intelligence is a specialty within computer science that is concerned with creating systems that can replicate human intelligence and problem solving abilities. They do this by taking in myriad of data, processing it and learning from their past in order to streamline and improve in the future.

In contrast, a normal computer program could need human interference in order to fix bugs and improve processes. According to Bhbosala, Puyari and Multan (2020) artificial intelligence is the branch of computer science that allows us to create intelligent machines that can behave like humans, think like humans and make decisions based on a logic program stored in memory. AI is a tool through which human efforts are reduced and substituted. AI can give answers to almost every questions asked by man. Attributes that made AI gain wide spread usage include capacity for independent through reasoning, planning and problem solving. To a greater extent, AI can think critically, apply logic, comprehend complexity and make decisions.

AI are classified into the basis of their capabilities. These include weak or narrow AI, general AI and strong AI (Oluwasegun & Abel, 2024). Explaining further;

1. Weak or narrow AI: This is a kind of artificial intelligence that lacks the ability to reason and can only carryout a predetermined limited set of commands. It is a form of AI that is most commonly employed worldwide. Example include IBM's, Waton supercomputer, Apple's siri, Alexa, Alpha Go and Sophia (Abel & Oluwasegun, 2024).
2. General AI: This is the kind of AI that can carry out tasks that humans can. According to Abel and Oluwasegun (2024) up until now, no computer has been able to think or function exactly like a person, but this could change in the near future.
3. Strong AI: It is anticipated that a time will come when computer would be able to perform tasks that human cannot. In summary, the main goals of artificial intelligence are to create machines that can perform tasks, requiring human intelligence, such as learning, reasoning, problem solving and perception. Key objectives of AI include automating repetitive tasks, enhancing efficiency and accuracy and fostering innovation through data analysis and creative applications. In addition, AI aims to improve decision making, provide personalized customer experiences, contribute to scientific progress, address societal challenges and ultimately, achieve general human like intelligence.

Advantages of Artificial Intelligence

Artificial Intelligence (AI) according to United Nations Education Science and Cultural Organization UNESCO (2023) has the potential to address some of the biggest challenges in education today to innovate learning and research and accelerate program towards quality education. The potential of using artificial intelligence in education is to enhance teaching, learning and research, assist teachers and encourage effective individualized learning. The following are some advantages of AI as a tool in teaching, learning and research.

1. Efficiency and automation: Teachers can concentrate more on developing creative lesson plans, engaging with students and conducting research by using AI to automate administrative tasks like scheduling and assignment grading.
2. Data - driven decision making: Artificial intelligence is capable of finding patterns and trends in students' achievement by analyzing huge data sets. Teachers can leverages on this and make well informed decisions about curriculum design, student interventions and teaching strategies.
3. Personalized learning: AI has the advantage of analyzing data on individual student performance to create learning strategies and materials that are specific to the strengths and weaknesses of individual student. This individualized approach can improve comprehension and student engagement.
4. Enhanced research: By automating data analysis, literature reviews and insight generation, AI tools can help industrial technology education teachers conduct research with ease. With this, research process can be quicken and more creative discoveries made.

5. Chat-bot and virtual assistant powered by AI: These tools can help students respond immediately to frequently asked questions on assignments and starting conversations. This contributes to the development of a more responsive and interactive learning environment.

Disadvantages of Artificial Intelligence

The use of AI in teaching can be a threat if the following are not checked.

1. Privacy: Using AI in education requires collecting, analyzing and interpreting a lot of data on staff and students. The greatest hurdle is ensuring the security and privacy of the data. Poor handling of staff and students data may result in security lapses and questionable entries.
2. Job displacement: Frederico Pistono, in a book titled: Robots will steal your job but that is OK, that the total number of jobs required by industry will be gradually reduced overtime, and each time we will have to reinvent ourselves, finding new occupations for the newly displace people by automation. This becomes very tiring after some time. It is a game you cannot win (Frederico Pistono, 2012). There are worries that the use of AI in education could result in the loss of jobs in specific roles, particularly those involving in administration and repetitive work.
3. Absence of human touch: AI is incapable of providing the same emotional intelligence and empathy that human educators can. An all-encompassing education depend on human interaction between teachers and learners, which AI might find difficult to replicate.
4. Depending on technology: If teachers and students rely completely on artificial intelligence, they may not be able to develop critical thinking and problem- solving skills because they will grow reliant on automated solutions.
5. Algorithms Bias: Artificial intelligence algorithms may inherit bias form the training data. Biased data that is used to train AI systems can lead to discriminatory outcomes that impact marginalized groups and reinforce already existing inequalities.

Teacher Education

No education can rise above the quality of the teacher. Teachers translate and implement educational policies, curriculum and assess learning outcome at the leaners level. The teacher carryout instructional leadership role, exert great influence on character formation and the process of socialization. Teachers preparation is the uppermost concern of educational planners and administrators. Teacher education is the provision of professional training and specialized training that take place within a prescribe period for the preparation of individuals who will thereafter inculcate, develop and nurture the upcoming generation into responsible and productive citizens. Teacher education equip prospective teachers with the knowledge, skills, attitude and behaviour they require to perform their professional duties credibly in the classroom, school, local and global society. Teacher education is a programme aimed at improving teacher proficiency and competence in order to enable and empower teachers to meet the demands of their profession and face the challenges that they encountered (Yusuf, 2022).

Stage of Teacher Education in Nigeria

Teacher education in Nigeria follows a phased, lifelong progression from pre-service training to induction and continuing professional development.

Pre-service training: This is the initial teacher training/education that encompasses teaching skills, sound pedagogical theory and professional skills (Ronald 2009 cited in Yusuf, 2022). Aspiring teachers at this phase acquire the necessary knowledge and skills before entering the classroom. Qualifications include the Nigerian Certificate of Education (NCE) from colleges of Education, Bachelor's Degrees in Education and Post-Graduate Diploma's and Master's and Doctorate degrees offered by university faculties of education for higher level specialization.

Induction stage: The induction phase deals with training and support given to teachers during their first few years in the profession to help them adapt and become effective in their roles. Induction is the time it takes for a beginning teacher to make the transition from student to teacher. Induction has the potential for teachers and administrators to act as supervisors, curriculum resource consultants or mentors (Ndayelechi, 2014). The process of teacher induction can also be described as a period to extend and enrich the teacher's experiential and knowledge base for successive years. Teachers development or continuing professional development refers to activities that improve a teacher's skills, knowledge expertise and other characteristics (Yusuf, & Dada, 2016). Teacher development can come in different ways. Formal or informal, through external expertise in the form of courses, workshops, or formal qualification programme, collaboration.

Constraints of Teacher Education in Nigeria

Numerous policies and reforms over time aimed at restructuring and repositioning teacher education for best global practices have been made. Despite these policies and reform teacher education in Nigeria faces numerous challenges.

1. Yusuf (2022) notes that the major problem of teacher education in Nigeria is the fact that teachers being trained now are not sufficiently prepared in order to meet the complex demand of the teaching process as regards school and colleges.
2. **Shortage of qualified teachers:** The universal basic education commission personal audit conducted in 2021 revealed shortage of qualified teachers at the primary school level. According to the report, 277,537 qualified teachers are needed to fill existing gaps. Kayode and Akanni (2016) reported that teachers are grossly in short supply in Nigeria both in quality and quantity. Shortage of teachers is so serious that some colleges with over two thousand student population have either only one teacher for each of the basic subject or none at all.
3. **In sufficient funding:** teacher education programme require significant investment in tools and machinery most often, the programme is underfunded leading to lack of necessary resources. The Federal Government's education budgetary allocation has been much below the UNESCO-mandated education funding baseline of at least 26% developing nation's annual budget. Oluwatosin and Bolanle (2024) said sufficient funding must be included in the budget for teacher training programme to be effectively implemented.
4. **Digital skill gap:** the 21st –century teaching and learning standard required that teachers at all teaching levels acquire digital skills, competences to enable them use digital tools and

strategies to enhance teaching and learning. This is not so with many institutions of teachers training the national board for technical education (NBTE) Monday, February 19th, 2024 launched an online workshop aimed at introducing digital literacy competency for technical vocational education and training (TVET) teachers. The training was tailored to equip TVET teachers in Nigeria with essential digital competence skills, use of digital tools for efficient lesson planning and delivery, develop and adapt digital content for vocational education, promote digital collaboration and communication in classroom and implement problem-solving strategies using digital tools.

Career Development

Career development for technical education teachers in Nigeria includes, pursuing higher qualifications, specializing in high demand fields, participating in Mandatory Continuing Professional Development (MCPD), building partnership with industries for curriculum input, students' placements and moving into administrative roles. Teachers can also grow by developing specialized competencies and contributing to national goals of industrial and economic development through skill training. Teacher development programmes aim to keep teachers' current with the latest advancement in their fields, allowing them to refresh and enhance their skills (Osiesi, 2020).

Types of professional development programmes

1. Induction training: Induction is a programme organized for new teachers aimed at introducing them to the teaching profession organizational structure, functions and scope of their responsibilities.
2. On-the-job training: On-the-job training is an internal or in-service type of training usually carried out by supervisors, fellow workers, mentors or managers to help employees adapt and acquire the right skills in a new profession (Haruna, Usman Abubaka, Adamu & Abubakar, 2025).
3. Off-the-job training: Off-the-job training refers to a variety of training methods that take place outside of the usual work environment including lectures, role-playing, case studies, discussion and simulations (Haruna, Usman Abubaka, Adamu & Abubakar, 2025). Professional development programmes for technical teachers are part-ways for the progressive updating of teacher's effectiveness and skills, knowledge of subject matter, and competency. It is a form of lifelong learning that encourages mutual collaboration between the teacher and his professional domain.

The Impact of Artificial Intelligence on Teaching Profession

The proponent of robotics, artificial intelligence and automation see no correlation between increased technological advancement and job loss or unemployment. Ge (2025) reported that a wide range of commentators, from academics to journalist to technologist have picked up the nation-arguing that even though the estimate of how many jobs and vulnerability to being replaced by machines and robots vary. however, it is clear that developing countries are more susceptible to automation compared to high income countries. This is become with the emergence of greatly improved competing power of artificial intelligences and robotics, a much larger scope of

occupation are at risk and vulnerable to automation is now based on whether jobs and tasks are co-definable and whether they are routine or not (Ge 2025).

Nigeria is a developing country and the teaching profession is vulnerable to the impact of robotics, artificial intelligence and automatic due to several factors. Below are some key factors contributing to this vulnerability

1. **Low skill levels and education Gaps:** The 21st – century is described as the digital literacy era where a person technology self-efficacy and cognitive skills are utilized to search asses, create, and disseminate information with the use of technology. therefore, an individual must possess adequate cognitive and technological skills and utilize technology effectively. Unfortunately, teachers especially from developing countries are not well prepared for embracing technology (Ahmed, Soomro and Nagvi 2025). This leaves the teacher vulnerable to displacement.
2. **Limited technological infrastructure:** Many developing countries lack the necessary technological infrastructure to integrate advanced robotics and automation effectively. Infrastructure such as high-speed internet, electrical grid instability makes it difficult for teachers from developing countries to keep up with technological advancement.
3. **Weak regulatory frameworks:** May developing nations have regulatory frameworks and labours laws that are ill - equipped to handle automation and its effect on employment. This could lead to unregulated, rapid displacement of workers without proper measures for retraining or reskilling.

The Way Forward

1. **Investing in education and skill development:** as automation takes over routine and low- skill tasks workers especially teaches can be retrained to handle more complex, high-skill roles. It is crucial to align educational curricula with the needs of digital economy
2. **Encouraging entrepreneurship and innovation:** encouraging entrepreneurship can help in creating new job-opportunities. Government and non-governmental organization can support small and medium-sized enterprises (SMEs) by providing access to capital, infrastructure, and training.
3. **Social protection and safety Nets:** social protection measures, such as unemployment benefits, retraining programme and pension schemes safety net can help vulnerable workers transition to new opportunities

Conclusion

The integration of artificial intelligence in education comes with advantages and disadvantages. while some commentators see it as a threat to job security in the teaching profession others describe it as a tool that enhance teaching learning and research. For its proper adoption by teachers, training and retraining through teacher education and career development for digital skills acquisition is necessary to overcome the fear of work force loss in the teaching profession, investing in

education, skill development, encouraging entrepreneurship and innovation as well as creating social protection nets for teachers in developing countries become topmost priority.

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AI-ENHANCED COGNITIVE DEFUSION COUNSELLING: A SCALABLE MODEL FOR STEM STUDENTS AND FUTURE WORKFORCE IN KWARA STATE

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Abstract

School avoidance behaviour undermines attendance, engagement, and academic achievement. It silently disrupts the STEM talent pipeline, as emotionally disengaged students rarely transit into science and technology pathways. This paper presents an AI-augmented Cognitive Defusion Counselling Technique (CDCT-AI) designed to reduce avoidance tendencies and improve learner resilience. Using AI-driven chatbots and personalized reflective prompts, the system delivers continuous behavioural guidance, helping students detach from anxiety-based thoughts and re-engage with learning. The paper reports an experimental study conducted in Lafiagi, Kwara State, Nigeria and proposes a scalable Artificial Intelligence (AI) augmentation to enhance reach, fidelity and sustainability of CDCT-AI in school settings. Ten secondary school students received CDCT-AI. A paired-samples t-test comparing pretest and posttest scores on the academic dimension of school avoidance revealed a significant reduction: Mean-pre = 60.00, Mean-post = 22.60; $t(9) = 29.94$; $p < .001$. Building on these findings, we articulate an AI-enhanced CDCT model comprising: AI counselling chatbots for out-of-session reinforcement, adaptive micro-interventions delivered via mobile phones, analytics-informed case management dashboards for counsellors and optional immersive practice using low-cost simulations. The model was aligned with the UNESCO and OECD guidance on trustworthy AI and Nigeria's Data Protection Act and outline an implementation roadmap for schools in Kwara State. The integrated approach promises improved access, personalization, and continuity of care while preserving human oversight, ethics, and data protection.

Keywords: *Cognitive defusion, Acceptance and commitment therapy, school avoidance behaviour, artificial intelligence, chatbots, secondary school, Nigeria, data protection, UNESCO, OECD.*

Introduction

School avoidance behaviour, manifesting as lateness to assembly, poor classroom attendance, disengagement from cognitively demanding tasks, and avoidance of academic responsibilities poses a persistent challenge to student achievement and wellbeing (Kearney & Graczyk, 2014). In resource-constrained contexts such as Lafiagi, Kwara State, limited counselling personnel and high caseloads complicate the delivery of evidence-based interventions. Cognitive Defusion Counselling Technique (CDCT), an ACT process, teaches students to experience thoughts e.g., “I will not pass this exam” as transient mental events rather than literal truths, thereby reducing the emotional control such thoughts exert over behaviour (Hayes, Strosahl, & Wilson, 1999).

School avoidance behaviour is viewed as an overlooked barrier to STEM education and long-term workforce development. Students who disengage emotionally or physically from school seldomly

progress into science and technology pathways, resulting in a silent leakage in the talent pipeline. The intervention is to integrate natural language processing (NLP) chatbots and adaptive reflective exercises to guide students through defusion-based strategies that may help them detach from unhelpful thoughts, anxiety triggers, and school-related fears. Unlike traditional counselling models, the AI layer is expected to enable continuous monitoring, personalized reinforcement, and accessibility beyond school hours.

This paper has two goals: (1) to report results from a pretest–posttest study testing the effect of CDCT on the academic dimension of school avoidance among secondary school students in Lafiagi; and (2) to propose and detail an AI-enhanced CDCT model that retains counsellor leadership while leveraging AI to increase accessibility, fidelity, and personalization of supports consistent with international guidance on trustworthy AI and Nigeria’s legal framework (UNESCO, 2021; OECD, 2023; NDPA, 2023).

Research Question

What is the effect of AI-enhanced cognitive defusion counselling Technique on academic dimension of school avoidance behaviour among secondary school students in Lafiagi, Kwara State?

Hypothesis

There is no significant effect of AI-enhanced cognitive defusion counselling technique on academic dimension of school avoidance behaviour among secondary school students in Lafiagi, Kwara State

School Avoidance Behaviour and Academic Dimension

School avoidance is multidimensional, encompassing academic disengagement and emotional distress. Kearney (2016) frames school avoidance as a multidimensional phenomenon spanning categorical forms such as refusal, truancy, withdrawal, exclusion; dimensional continua such as absenteeism severity, functional profiles; and intersecting domains such as academic disengagement, emotional distress, and ecological context, informing a multi-tiered system of supports model. The academic dimension specifically reflects avoidance of learning tasks, homework, and classroom participation, which directly impairs achievement. Interventions targeting catastrophic cognitions about academic failure are especially effective for secondary school populations (Egger et al., 2003).

Evidence for Digital and AI-Supported Counselling

A growing body of research indicates that digital conversational agents and AI-supported tools can deliver CBT- and ACT-consistent strategies, reduce symptoms of anxiety/depression, and provide scalable support as adjuncts and a not replacement to human counsellors (Fitzpatrick, Darcy, & Vierhile, 2017; Inkster, Sarda, & Subramanian, 2018; Liu et al., 2024). Systematic reviews confirm benefits alongside cautions (Li et al., 2025; Vaidyam et al., 2019). These findings motivate an adjunctive role for AI within a counsellor-led CDCT program in schools.

Incorporating AI with Cognitive Defusion Counselling Technique in Schools

It is assumed that:

- i. School avoidance may result in loss of STEM talent pipeline such that students who avoid school rarely transit into science/technology careers.
- ii. AI in counselling may amount to a scalable student retention system that is unlike traditional counselling, AI can track, detect and intervene early when the need arises.
- iii. AI-enhanced cognitive defusion may result in psychological readiness for STEM Rigor in terms of emotional resilience which is as important as technical skills in the future workforce.
- iv. Cognitive defusion may be positioned as a guidance (a preventive measure) in STEM Education, solving behavioural problems before it becomes an academic nightmare.

Real-world implementation of CDCT in public schools often faces barriers such as; limited counsellor capacity, inconsistent session attendance, and difficulties sustaining practice between sessions. AI can address these challenges by offering:

- i. Out-of-session reinforcement via AI chatbots that guide brief daily defusion practices and values reminders.
- ii. Adaptive micro-interventions (two- to five-minute exercises) triggered by student check-ins, class schedules, or identified risk windows e.g., before examinations.
- iii. Fidelity support for counsellors through structured protocols, adherence prompts, and analytics on skill usage.
- iv. Increased access for students who cannot reliably attend in-person sessions, while preserving triage pathways for human care.

An AI-Enhanced CDCT Model for Schools

In this section, workflows, architecture overview and dashboards are discussed:

Ethics, Safety, and Legal Compliance

UNESCO in 2021 adopted the first global standard setting instrument concerning AI ethics, formally titled the “*Recommendation on the Ethics of Artificial Intelligence*”. This framework applies to all of its 194 member states and emphasizes key principles such as transparency, fairness, and critically human oversight of AI systems. Human oversight means that AI must not operate unchecked, be it within counselling or educational interventions. Instead, there must always be a responsible human authority monitoring outputs, ensuring ethical behaviour, and stepping in if the AI diverges from intended purpose. The OECD, through its AI policy observatory, promotes similar principles, centered on trustworthy and responsible AI. While the exact phrasing in 2023 also underlines human oversight, it's part of their broader push for AI systems that are transparent, accountable, and aligned with human-centered values. This, implies that any AI tools should remain supervised by trained human counsellor who can interpret, override, or guide AI outputs upholding ethical standards and safeguarding students (clients).

Furthermore, Vaidyam et al. (2019) conducted a review on the use of chatbots and conversational agents in mental health (psychiatric and psychological contexts). They highlighted significant gaps including concerns around confidentiality, privacy, security, liability, and the lack of consensus in practices or standards for crisis situations. Although they did not prescribe a specific “crisis protocol,” their work underscores the imperative of establishing clear procedures when leveraging

AI in sensitive contexts, especially where a student may express suicidal thoughts or emotional crisis.

Studies (for example, AI systems detecting mental health crises via social media) have noted the best practices to include developing a crisis response protocol in partnership with mental health professionals, conducting ethical audits, and setting up safeguards like privacy compliance and advisory review boards. The implication here is the need for a formal crisis protocol which might include:

1. Direct escalation to a human counsellor.
2. Immediate notification of guardians (in line with ethics and consent).
3. Triage procedures for urgent or emergency referrals.
4. Ethical logging and audit trails.

The Nigeria Data Protection Act (NDPA, 2023) creates a robust legal framework for handling personal data, specifically in Nigeria. Key highlights include:

Establishment of the NDPC: The Act, signed into law on June 12, 2023, establishes the Nigeria Data Protection Commission (NDPC) to administer and enforce data protection, replace previous regulations (NDPR 2019), and set policies and penalties with the scope applying to any data controller or processor in Nigeria or elsewhere processing data of Nigerian residents. It also includes those located abroad if they process Nigerian data subjects

Key Features and Requirements

1. **Lawful Bases for Processing:** Broadens legal grounds to include legitimate interest for example, AI use in research or service improvement, while preserving fundamental rights;
2. **Data Protection Impact Assessments (DPIAs):** Mandatory DPIAs for high-risk processing activities such as automated AI-driven profiling or children's data usage;
3. **Cross-Border Transfer Rules:** Transfers only allowed if recipient jurisdiction has adequate safeguards—or under specific exceptions like consent or public interest;
4. **Data Protection Officers (DPOs):** Organizations of major importance (those processing large volumes or sensitive data) must appoint a DPO and register with the NDPC;
5. **Breach Notification:** Organizations must notify both the NDPC and affected data subjects **within 72 hours** of discovering a security breach;
6. **Enforcement Powers and Penalties:** The NDPC can fine organizations—up to ₦10 million or 2% of annual turnover (for major players), ₦2 million or 1% for SMEs—and can issue compliance mandates, suspend processing operations, and even pursue criminal prosecution; and
7. **GAID 2025 Update:** The NDPC issued the General Application and Implementation Directive (GAID), effective September 19, 2025, which further defines obligations like periodic audits, data privacy policy transparency, and semi-annual reporting.

Architectural Overview

Tier 1 (Student App / WhatsApp Channel): A lightweight, privacy-preserving conversational agent reinforcing CDCT skills: labeling thoughts, defusion drills, values prompt, and committed action planning. Content is culturally localized (examples drawn from Nigerian classrooms and exams). Offline-first design caches exercises for low-connectivity contexts.

Tier 2 (Counsellor Dashboard): An analytics and case-management panel showing (a) aggregate engagement (time-on-task, exercise completion), (b) flagged risk indicators e.g., repeated catastrophic predictions, and (c) adherence to counsellor-assigned home practice. No raw free-text is displayed by default—only de-identified summaries unless counsellor requests specific logs with consent.

Tier 3 (Safety and Escalation): Clear boundaries: the AI does not diagnose, prescribe, or manage crises. Crisis language triggers scripted, locally relevant signposting e.g., school counsellor contact, parent/guardian notification protocol, and national/NGO helplines where available. Human review is mandatory for all escalations.

Core CDCT Digital Workflows

Daily Thought Labeling: Students log one challenging thought and reframe using “I am noticing I’m having the thought that...”. The agent prompts for cognitive distance ratings before/after.

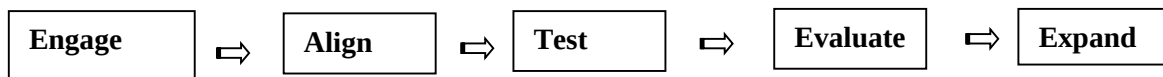
Defusion Drills Library: 2–5-minute audio/text exercises (e.g., silly-voice repetition, leaves-on-a-stream visualization, word repetition) tagged by context (tests, oral presentations, homework).

Values-to-Action Planner: Micro-goals aligned to values (e.g., learning, perseverance, integrity) with next-step reminders (e.g., “Open your math notebook for 10 minutes”).

Pre-Exam Protocol: A scripted 3-step routine: paced breathing (60–90 seconds), “thoughts-as-thoughts” drill, and a one-action commitment (“start

Implementation Roadmap for Schools in Kwara State

This roadmap would allow schools in Kwara State to implement CDCT (AI) incorporated or systematically, ensuring sustainability and stakeholder ownership. It follows the algorithm



Stakeholder Engagement

This stage is about building ownership, trust, and alignment among all key actors.

- i. **Identify stakeholders:** Ministry of Education, Teaching Service Commission, school administrators, teachers, parents, students, community leaders, religious institutions, NGOs, and education-based unions.
- ii. **Consultation forums:** Organize town hall meetings, focus group discussions, and workshops to explain the purpose of the initiative (e.g., new policy, counselling programs, digital tools, or curriculum reforms).

- iii. **Awareness creation:** Develop communication strategies (radio programs in Yoruba, Nupe, Hausa; school newsletters; WhatsApp groups for parents).
- iv. **Partnerships:** Involve local NGOs, teacher associations, and donor agencies to provide technical and financial support.
- v. **Buy-in:** Secure commitments through Memoranda of Understanding (MoUs), joint committees, or advisory boards.

Compliance and Regulatory Alignment

This ensures that the initiative aligns with policies, standards, and ethical frameworks ensuring the (Ethics, Safety, and Legal Compliance) as earlier discussed and to include:

- i. **Policy review:** Cross-check with the National Policy on Education, Kwara State education policies, and federal directives such as UBEC requirements.
- ii. **Legal framework:** Ensure the program adheres to child protection laws, safeguarding guidelines, and examination ethics.
- iii. **Capacity building:** Train teachers and administrators on new guidelines, codes of conduct, or counselling frameworks.
- iv. **Monitoring mechanisms:** Establish compliance units at local schools and zonal levels for supervision.
- v. **Documentation:** Create manuals, reporting templates, and checklists for standard practice.

Pilot Implementation

Before rolling out fully, test the idea in a manageable scope.

- i. **Selection of pilot schools:** Choose a mix of urban, peri-urban, and rural schools across Lafiagi, Ilorin, Offa, etc., for diversity.
- ii. **Resource deployment:** Provide necessary tools (training modules, digital devices, counselling frameworks, monitoring kits).
- iii. **Capacity strengthening:** Train a core group of teachers, counsellors, and administrators as “champions” of the program.
- iv. **Implementation period:** Run the pilot for 1–2 academic terms.
- v. **Data collection:** Monitor attendance, behavioural changes, teacher adoption, parental involvement, and student outcomes.

Evaluation and Feedback

This stage checks what worked, what failed, and how to improve.

- i. **Monitoring & evaluation framework:** Develop KPIs (e.g., attendance rates, reduction in avoidance behaviour, improved exam ethics, teacher satisfaction).
- ii. **Feedback loops:** Conduct surveys, interviews, and focus groups with students, teachers, and parents.
- iii. **External assessment:** Partner with universities (e.g., University of Ilorin, Kwara State University) for independent evaluation.
- iv. **Refinement:** Adjust strategies (e.g., change training methods, improve communication, address resistance).
- v. **Reporting:** Publish findings in reports, policy briefs, or educational conferences for transparency.

Scale-Up and Institutionalization

After proving effectiveness, expand and sustain the program.

- i. **Gradual expansion:** Roll out to more schools in phases (by Local Government Areas, then state-wide).
- ii. **Institutional framework:** Integrate the initiative into existing structures; curriculum, school inspection systems, or teacher training colleges.
- iii. **Capacity building at scale:** Train more teachers, school heads, and education officers.
- iv. **Sustainability measures:** Secure funding through state budgets, donor support, and community contributions; Embed monitoring into the State Quality Assurance Agency's routine checks.
- v. **Policy adoption:** Push for state-wide policy endorsement by the Kwara State House of Assembly or Ministry of Education.
- vi. **Knowledge sharing:** Showcase Kwara State as a model to other Nigerian states through conferences and inter-state exchanges.

Theoretical and Empirical Background

Acceptance and Commitment Therapy and Cognitive Defusion

ACT posits that psychological inflexibility often driven by cognitive fusion (over-identification with thoughts) and experiential avoidance maintains maladaptive patterns. Cognitive defusion techniques such as labeling thoughts as “I’m having the thought that...”, repeating words until they lose literal meaning, or noticing thoughts as passing events. All weaken the literal believability of distressing cognitions, thereby reducing avoidance and enabling values-consistent action in school settings (Hayes et al., 2012; Angela & Tondok, 2021).

Methodology

Design

A one-group pretest–posttest quasi-experimental design was employed to examine the effect of CDCT on the academic dimension of school avoidance.

Population and Sampling

Ten secondary school students from Government Secondary School Lafiagi, Kwara State who met screening criteria for elevated school avoidance on the academic dimension participated with school approval. The students were identified with the use of a checklist (SABQ; academic dimension) and were considered to be in dare need of the intervention.

Instrumentation

A validated School Avoidance Behaviour Questionnaire adapted from General and Specific Avoidance Questionnaire GSAQ by Stemmet et al. (2015) was used to measure pre-intervention and post-intervention scores.

Procedure

Participants received structured CDCT delivered by a trained counsellor for 6–8 weeks. Core components included psychoeducation about thoughts-as-thoughts, defusion exercises such as “I’m having the thought that...”, word repetition, mindfulness of thoughts, values clarification related to education, and committed action plans.

Data Analysis

A paired-samples t-test compared pretest and posttest mean scores on the academic dimension of school avoidance at $\alpha = .05$.

Results

H01: There is no significant effect of AI-enhanced CDCT on the academic dimension of school avoidance behaviour among secondary school students in Lafiagi.

Table 4. Paired-samples t-test

Variables	N	Mean	SD	t	df	p
Pretest	10	60.00	2.98			
Posttest	10	22.60	1.34	29.94	9	.000

The reduction from pretest ($M = 60.00$) to posttest ($M = 22.60$) was statistically significant, $t(9) = 29.94$, $p < .001$, indicating a large effect of AI-enhanced CDCT on academic avoidance. Thus, the null hypothesis is rejected.

Discussion

The findings confirm AI-enhanced CDCT has effect on reducing academic avoidance. Students reframed negative self-predictions as mere thoughts, consistent with prior ACT findings (Hayes et al., 2012; Angela & Tondok, 2021). The challenge is scalability. Studies on AI mental health chatbots (Fitzpatrick et al., 2017; Inkster et al., 2018; Liu et al., 2024) show that automated reinforcement of therapeutic skills is feasible. For Nigerian schools, AI-assisted CDCT can address gaps in counselling resources and enhance continuity of practice. The results support CDCT as an

efficacious school-based intervention for academic avoidance. By shifting students' relationships with discouraging cognitions e.g., "I will fail this test", "I can't make it in school" CDCT reduces the emotional impact of such thoughts and promotes task engagement. These findings align with the broader ACT literature on defusion and with digital mental health evidence showing that structured, skills-based content can be delivered at scale.

Conclusion

The finding of this study demonstrate that AI-enhanced Cognitive Defusion Counselling Technique (CDCT) was effective in significantly reducing academic avoidance behaviour among secondary school students in Lafiagi, Edu Local Government Area of Kwara State. By helping students detach from unhelpful thoughts and reframe their cognitive patterns, CDCT contributed to improved class attendance, greater willingness to participate in academic activities, and enhanced engagement with learning tasks. The integration of Artificial Intelligence (AI) augmentation further highlights the potential for scaling, reinforcing, and sustaining these gains. AI-driven supports such as chatbots, digital reminders, personalized learning prompts, and adaptive counselling modules, can extend the reach of CDCT beyond the counselling room, offering students ongoing reinforcement in real time. In particular, AI has the capacity to provide personalized interventions tailored to individual learning needs, track progress, and deliver consistent feedback that complements the work of human counsellors. This creates opportunities for scalability, ensuring that more students across Kwara State, including underserved communities, can benefit from structured counselling support.

However, the promise of AI-driven student support infrastructure must be balanced with a strong commitment to ethical safeguards. Issues of privacy, data protection, cultural sensitivity, inclusivity, and human oversight must remain at the forefront of implementation. Without such safeguards, AI applications risk undermining trust, excluding vulnerable learners, or introducing unintended biases into counselling practices. In sum, this study underscores the value of combining evidence-based counselling techniques such as CDCT with innovative digital tools to address pressing challenges in Nigerian secondary schools. While the results are promising, the approach must be refined through broader research, careful monitoring, and ethical alignment with local realities. With proper design and policy support, CDCT augmented by AI has the potential to provide a sustainable, scalable, and culturally responsive framework for improving student engagement and reducing school avoidance behaviour in Kwara State and beyond.

Recommendations

Based on the findings of the study, it was recommended that:

1. School counsellors be encouraged in the use of AI- enhanced cognitive defusion in helping students against academic avoidance and towards academic engagement
2. School counsellors be engaged in workshop trainings that encourage the use of cognitive defusion counselling technique on
3. School counsellors be engaged in workshop trainings that encourage the integration of AI in counselling

Limitations and Future Research

Small Sample Size (n = 10): The present study relied on a very limited sample, which reduces the generalizability of findings. While the outcomes suggested potential benefits of integrating AI into

CDCT for addressing school avoidance behaviour, a small group does not adequately represent the broader population of secondary school students in Kwara State or beyond. Variations in cultural background, socio-economic status, and school environment could yield different results if a larger sample were studied.

Focus on the Academic Dimension Only: The intervention was tested mainly on the academic dimension of school avoidance behaviour (e.g., poor class attendance, avoidance of assignments, lack of participation). Other critical dimensions emotional (e.g., anxiety, fear of failure), conflict-related (e.g., peer disputes, teacher-student clashes), and help-seeking behaviours were not directly examined. Since CDCT + AI has the potential to address multiple domains of avoidance behaviour through personalized prompts, chatbot interactions, or adaptive learning, this narrow focus limits the scope of findings.

Digital Literacy Barriers: The integration of AI into CDCT assumes a baseline of digital literacy among students, teachers, and counsellors. However, in many Kwara State schools, especially in rural areas such as Lafiagi, limited access to digital devices, poor internet connectivity, and low ICT skills could hinder effective implementation. This means that the outcomes observed may not be easily replicable in schools with limited resources, and students with low exposure to digital technologies may struggle to fully benefit from AI-supported CDCT.

Ethical and Practical Constraints: AI-driven student support infrastructure raises ethical concerns around data privacy, confidentiality, and reliance on automated systems. In this study, safeguards were put in place, but the small scale limited the exploration of broader issues such as AI bias, cultural sensitivity of AI-generated content, and the balance between human counsellor oversight and machine-guided interventions.

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BASIC EDUCATION REFORM IN THE DIGITAL ERA: EXPLORING THE ROLE OF ARTIFICIAL INTELLIGENCE (AI) IN ENHANCING QUALITY BASIC EDUCATION IN NIGERIA

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Abstract

The urgency of re-engineering the education system has reached unprecedented level in today's world. This imperative arises from the lightning-fast pace of digital technology progress, the dynamic evolution of societal demands, and the ever-changing landscape of pedagogical theories. These factors collectively emphasize the imperative to rethink education delivery systems, reimagine learning environments, and embrace innovation to confront the multifaceted challenges of the contemporary world. This position paper explores diverse role of AI on reform and excellence in basic education, delving into their significance, outlining pivotal strategies, and illuminating the potential advantages they hold. As we live in this era of digitization, the transformation of basic education becomes not just a necessity but an attribute of hope, guiding us toward a future of empowered individuals and a thriving nation.

Keywords: *Digital Era, Artificial Intelligence, Basic Education Reform*

Introduction

The world is progressing very rapidly due to the development in Information and Communication technology (ICT) that is currently been experienced globally. This is characterized by highly advance digital technologies like Artificial Intelligence (AI), Internet of Things (IT), robotics engineering, Virtual Reality (VR) and digitization that brings about transformation of different sectors of the economy, including agriculture, commerce, health, politics and education across the globe.

There has been a growing recognition of the critical role that digital technology plays in shaping and improving various aspects of our lives. From communication to healthcare, from agriculture to sports, technology has revolutionized the way we operate and interact with the world. In the field of education, the impact of technology has been particularly significant, with its potential to transform the traditional teaching and learning approach and enhance academic outcomes (Onyanabo, 2024). However, in the context of Nigeria, this transformation through the use of technology tools has not had the same far-reaching and sustainable effect on education as in other countries of the world. Adeoye and Alabi (2022) reported that there have been isolated pockets of success and good practice, largely at the other levels leaving behind the basic education level.

Basic education is the foundational education crucial for national development. In Nigeria, basic education is encompassing primary and junior secondary education. Governed by the Universal Basic Education (UBE) Act of 2004, its goal is to provide free, compulsory, and qualitative education for every child irrespective of location, economic status, or cultural background. However, despite its free and compulsory education policy, the basic education system in Nigeria

faces numerous and complex challenges. Most noticeable is the current teacher supply and quality gaps, infrastructural decay and resource constraints, and very unsatisfactory pupils' learning outcomes among others (Universal Basic Education Commission [UBEC], 2022). These challenges have fuel the growing need for reform, with the researchers calling for a transformation of basic education delivery system if Nigeria is to meet the dynamic demands of contemporary society.

As the world is undergoing a profound transformation, marked by a growing demand for skills rooted in the ability to understand, apply, and innovate with technology, there is need to bridge the gap between traditional education frameworks designed for the industrial age and the demands of 21st century learners and the evolving job market. Incorporating Artificial Intelligence (AI) into the curriculum will involve more than merely using computers in classrooms but a comprehensive overhaul of teaching pedagogies and learning objectives (Ganiyu *et al.*, 2024). Artificial Intelligence which is about the ability of machines or computer systems to mimic human intelligence and perform tasks that typically require human intelligence, such as learning, reasoning, problem-solving, and decision-making among others is making significant impact in education.

AI tools have been incorporated into education system in order to address some of the challenges faced by the sector, particularly in areas of quality and access. Furthermore, its applications in education is basically tailored to promoting personalized learning, data-driven decision-making, and enhanced student engagement, and assessment among others. Chen *et al.* (2020) stressed further that the importance of AI is providing tailored educational experiences, helping students learn at their own pace and improving retention rates. With adaptive learning platforms, AI has the capacity to modify lessons in real-time based on individual student performance, offering customized feedback and learning materials. Olatunde-Aiyetunde *et al.* (2024) reiterates that AI tools could support teachers in managing large classes by automating grading, assessing student progress, and facilitating administrative tasks.

AI's potential in education is expanding beyond developed regions, with countries in Africa beginning to recognize its transformative capabilities. However, the application of AI in developing countries like Nigeria, is at its early stage and often hindered by limited funding which restricts the acquisition of necessary technologies and training for educators (Adebayo *et al.*, 2022; Eze & Olusola, 2023). Chukwuemeka *et al.* (2025) noted further that infrastructural limitations, such as unreliable internet connectivity, power shortages, and lack of AI-equipped devices, restrict the effective adoption of AI tools in Nigerian schools.

However, the quality of education particularly at the elementary level remains a pressing concern. The 2022 National Assessment of Learning Outcomes undertaken by UBEC (2022) revealed that over 50% of Primary 4 pupils could not read and comprehend a simple text, and 60% lacked basic numeracy skills. The situation is still far from better as revealed in 2024 UNICEF report on the state of education in Nigeria. This crisis is compounded by a pupil-to-teacher ratio that often exceeds 50:1, insufficient instructional materials, and persistent and students'/teachers' absenteeism (World Bank, 2024). These factors create a system where children are attending school but are not learning effectively, and many are out of school. Hence, the quality of education, particularly the basic education has been negatively affected, hindering the country's progress

towards achieving economic growth and sustainability. In this article, the researcher explores the role of artificial Intelligence in enhancing quality reform of the basic education in Nigeria.

Conceptualisation

Basic Education in Nigeria: A System in Need of Transformation

Basic education is the foundation of any education system. It is the education given to children aged 0-15 years. It includes 6 years of primary education and 3 years of Junior Secondary education. Equally, it covers special interventions directed at nomadic, pastoralist and migrant fisher-folks, mass literacy as well as the Almajiri and other vulnerable and excluded groups (Federal Ministry of Education 2024-2030 road map). The agency responsible for the implementation of basic education is the Universal Basic Education Commission (UBEC) at the federal level and State Universal Basic Education Board (SUBEB) at the state level. The Universal Basic Education (UBE) programme was designed to be a tool for achieving some of the “Education for All” goals as articulated in the Dakar Framework of Action (2000) (FME, 2024). These include:

1. Expanding and improving comprehensive early childhood care and education, especially for the most vulnerable and disadvantaged children.
2. Ensuring that by 2015, all children, particularly girls, children in difficult circumstances and those belonging to ethnic minorities, had access to, and completed, free and compulsory primary and junior secondary education of good quality.
3. Eliminating gender disparities in primary and junior secondary education by 2005, and achieving gender equality in education by 2015, with a focus on ensuring girls’ full and equal access to and achievement in basic education of good quality.
4. Improving all aspects of quality of education.
5. Ensuring excellence so that recognised and measurable learning outcomes are achieved by all, especially in literacy, numeracy and essential life skills.

Therefore, the basic education is fundamentally set to provide the child with diverse basic knowledge and skills for entrepreneurship, wealth creation and educational advancement (UBEC, 2022). However, the attainment of the objectives of basic education depends on provision of adequate infrastructure, effective planning, coordinated policy formulation and implementation, relevant and functional curriculum, massive investment on infrastructures and deployment of adequate qualified teachers to effectively deliver the curriculum (UBEC, 2022). Therefore, as we live in this era of digitization, the transformation of basic education becomes not just a necessity but an attribute of hope, guiding us toward a future of empowered individuals and a thriving nation.

Challenges of Basic Education in Nigeria

As instrumental as basic education is for individual and national development, it is not without challenges. Some of the major challenges of Basic Education in Nigeria identified in previous studies such as Adu and Opone (2020); the World Bank (2021), and FME (2024-2027), Roadmap include:

1. Teacher shortages, uneven quality of teaching, and lack of continuous professional development.
2. Teachers are not sufficiently equipped to implement the national curriculum.
3. Dilapidated and inadequate classrooms and others school structures.
4. Dearth of textbooks and other instructional materials.
5. Insufficient capacity at State and Local Government levels to implement fully UBE programmes.
6. Weak monitoring and evaluation systems.
7. Socio-cultural and economic barriers that create gender imbalance in basic education.
8. Low enrolment, retention and completion rates.
9. Insufficient deployment of educational technology in basic education delivery.
10. Over-emphasis on the cognitive over psychomotor and affective domains.

Hence, the system is characterized by a one-size-fits-all curriculum delivered in overcrowded classrooms, filled with individual learning paces and styles, leading to widespread disengagement, poor outcomes, and increase dropout.

Possible Ways of Addressing the Basic Education Challenges

The possible strategies and actions that need to be taken to address the challenges of basic education in Nigeria are:

1. Leverage the teacher training institutions to address current teacher supply gaps in basic education schools.
2. Leverage AI opportunities to enhance the quality of teachers, administrators and school supervisors in basic education schools.
3. Provide adequate educational technology resources, including bandwidth in teacher training institutions to enhance digital skills of educators.
4. Restructure the teaching and learning environment to be ICT-driven by providing classrooms in all schools, including special education with requisite ICT infrastructure and services.
5. Conduct adequate monitoring and evaluation to ensure that quality and set standards are maintained in Basic schools.
6. Undertake review of Basic Education curriculum and ensure a blended approach incorporated.
7. Encourage the use of AI to provide relevant and updated text books and other learning materials to ensure the attainment of the learning outcome benchmarks.
8. Provide training centres for entrepreneurship in Basic Education Schools
9. Engage the traditional and religious leaders to commit to high-level girl-child education advocacy in their various domains.

Understanding AI in Educational Context

Artificial Intelligence has to do with the ability of machines or computer systems to mimic human intelligence and perform tasks that typically require human intelligence, such as learning, reasoning, problem-solving, and decision-making among others is making significant impact in education (Onyanabo, 2024). AI in Education is an interdisciplinary field that uses AI techniques like machine learning, natural language processing, and data analytics to solve educational problems. Its primary goal is to create adaptive learning environments that respond to the needs of

individual learners (Luckin *et al.*, 2022). The key AI technologies relevant to basic education identified include:

- a. **Intelligent Tutoring Systems (ITS):** Made up of computer systems that provide immediate and customized instruction or feedback to learners without human teacher intervention, ITS has the ability to guide a pupil through step-by-step process to solving a maths or any other problem. These AI "tutors" can provide 24/7 support, answering questions and guiding students through problems, which is crucial for reinforcing learning outside school hours (Graesser *et al.*, 2018).
- b. **AI-powered software** can assess a student's knowledge level and learning style, then deliver customized lessons and exercises (VanLehn, 2011).
- c. **Automated Assessment and Feedback:** AI can grade assignments and provide instant feedback, freeing up teachers to focus on adequate preparation of instruction (Wang *et al.*, 2020).
- d. **Natural Language Processing (NLP)**, that enables machines to understand and generate human language. its powers applications like automated essay scoring, reading comprehension assistants, and language learning apps (e.g., chatbots for practicing English) to guide pupils to effective language learning.
- e. **Learning Analytics**, which has to do with the measurement, collection, analysis, and reporting of data about learners and their contexts to understand and optimize learning (Luckin *et al.*, 2022). It can identify at-risk pupils and predict learning gaps.

Role of Artificial Intelligence in Achieving Reform and Excellence in Basic Education in Nigeria

One of the key ways to improve the basic education system in Nigeria is the integration of educational technology like the AI. With the rapid growth of digital technology, pupils today are digital natives, and thus, require education in a format that best suit their learning styles. Variety of teaching and learning activities can be accomplished using artificial intelligence at the basic education level. From teaching and learning, and pupils support, to assessment and feedback, AI tools are adequately used to perform different educational services. The following are some roles AI can play in transforming basic education in Nigeria:

Enhancing Learning and Teaching: Educational technology resources, whether hardware, software, digital devices, and online resources can be used to create interactive and engaging learning experience for learners. Adu and Opone (2020) have opined that by implementing comprehensive education technology reforms, basic education schools can actively enhance teaching and learning, bridge the gap between theory and practice, and foster understanding and retention of complex concepts.

Provision of Personalized Learning Paths: AI approach is essentially supporting personalized learning to the specific needs, interests, and abilities of each student, which enables teachers to customize their teaching methods and create tailored lesson plans effectively (Luckin *et al.* 2022). This allows students to learn at their own pace and style, rather than adhering to a traditional system

of one-size-fits-all curriculum delivery system. For instance, an AI-powered platform like Nigeria's own Mavis Tutor can assess a pupil's current understanding of a topic like Fractions and then serve up customized lessons and practice exercises that match pupil's proficiency level (Oyelere et al., 2023). This approach can help to improve learning outcomes by tailoring education to the specific needs of each pupil and ensure that no child is left behind.

Developing Digital Literacy: Maguire (2023) have opined that integrating AI into the education like the basic education curriculum will help pupils develop essential digital literacy skills essential for their future careers and for effective participation in a digital society.

Bridging Educational Disparities: Implementation of educational technology and essentially AI support in basic education systems will play a pivotal role in bridging educational disparities and ensuring equitable access to quality education among marginalized minority groups, individuals with disabilities, and those from disadvantaged socioeconomic backgrounds (Olumorin et al., 2022). For instance, AI education support tools like the virtual classrooms can provide access to quality education for students in remote or underserved areas, where physical classrooms may be limited or non-existent. This can help bridge the gap in educational opportunities and significantly reduce the number of out of school children in Nigeria.

Improved Teaching Practices: AI tools can assist teachers in creating more effective instructional strategies by analysing data on student performance, identifying areas where additional support may be needed, and suggesting relevant teaching materials (Akinrinola & Chukwuma, 2024). This can help teachers tailor their teaching methods to the specific needs of their students, resulting in improved teaching practices and better student outcomes.

Improving Foundational Literacy and Numeracy

AI-powered applications can be game-changers for literacy and numeracy gaps currently being experienced in basic education schools. AI app like ReadAlong by Google, which uses speech recognition to help children learn to read, could be adapted to improve literacy in basic education schools in Nigeria. Similarly, adaptive learning games can make mastering basic numeracy skills engaging and interactive, providing immediate feedback that is crucial for early learning (Bakar *et al.*, 2023).

Enhanced Creativity and Critical Thinking

AI-powered educational tools can foster creativity and critical thinking skills in students by providing opportunities for problem-solving, analysis, and decision-making (Bakar *et al.*, 2023). Virtual simulations and interactive learning experiences can engage students in hands-on learning, allowing them to develop their creativity and critical thinking skills, which are essential for the workforce of the future.

Integration of AI technologies into basic education in Nigeria will offers a promising pathway to building a quality education. By leveraging technological tools and opportunities AI offer, Nigerian can overcome the existing challenges of basic education, while promoting academic excellence.

Considerations and Prerequisites for Successful Implementation of AI in Basic Education in Nigeria

Evidently, researches have shown that the integration of AI tools in Nigerian education has the potential to revolutionize the education landscape by providing innovative solutions to existing challenges and improving the quality and accessibility of education. However, there are several key considerations that need to be addressed for effective implementation and responsible use of AI in basic education in Nigeria.

Teacher Training and Capacity Building

The effective use of AI tools in education requires skilled educators who are proficient in using these technologies. However, lack of adequate training and capacity building opportunities for educators in Nigeria is a major treat to effective integrate AI tools into the basic education. This can hinder the full realization of the potential benefits of AI in education. A massive investment in professional development is required to build "AI readiness" and ensure teachers are co-designers of the process, not passive recipients (Eze *et al.*, 2024).

Data Privacy and Security

AI tools in education often rely on the collection and analysis of large amounts of data, including pupil's performance data and personal information. Ensuring the privacy and security of this data is crucial to protect the rights and interests of students and educators. There may be concerns about the misuse or unauthorized access to student data, and appropriate measures need to be in place to safeguard data privacy and security. In fact, Nigeria must develop and enforce robust data protection laws, like the Nigeria Data Protection Act (2023), specifically for the education in the basic education sector.

Ethical Considerations

AI raises ethical concerns in education, such as bias in algorithms, fairness, transparency, and accountability. AI models that worked on foreign data may not perform well in the Nigerian context, potentially reinforcing biases. Therefore, it is crucial to develop and train AI systems on locally relevant datasets. This is to ensure that AI tools are designed and implemented in an ethical manner, taking into consideration issues of bias, discrimination, and social impact. Ethical guidelines and frameworks should be in place to ensure responsible and ethical use of AI in basic education in Nigeria.

The Need for a Multi-Stakeholder Implementation Roadmap to Ensure Access and Equity

One of the major challenges that could limits the adoption of AI tools in Nigerian basic education is equitable access, particularly for students in rural and underserved areas with limited internet connectivity and technological infrastructure. There is a risk that if this challenge is not adequately taken into consideration the benefits of AI tools may only be accessible to students in urban areas or those with more resources, exacerbating existing disparities in basic education. Therefore, a multi-stakeholder implementation roadmap must be developed. The government must lead in policy formulation, infrastructure investment that will ensure provision solar-powered digital hubs for basic education schools, and funding research for locally developed AI education solutions. Also, the private sector need to partner with the government to develop affordable, offline-first AI tools that are contextually and culturally relevant to basic education.

Position Statement

This paper posits that for basic educational to truly make a difference in achieving holistic excellence, it is vital to build a systematic and sustainable model for integrating digital innovations, including AI into basic education curriculum. This is because when AI is deployed strategically and equitably, it will present a transformative opportunity to leapfrog systemic barriers in education and directly enhance the quality, accessibility, and transformation of basic education in Nigeria. More so, the paper posits that for teachers to achieve academic excellence, AI should be viewed as a powerful assistive tool to augment teachers' efforts, not replace them, and to create more efficient and effective learning ecosystems. Therefore, effective teacher training to stay abreast of the development in AI and other educational technologies, is a catalyst for basic educational improvement, which ensures that educators contributes to its reform. Hence, enhancing the digital skills of teacher-educators is a vital step towards holistic reform of basic education in Nigeria.

Conclusion

This paper posit holistic reform and excellence in basic education, the role of digital educational technologies like the AI should not be overlooked. This is because not only does the use of AI enhanced teaching and improves learning outcomes, it provides learners with personalized education experiences, and offers possibilities to bridge the gap between theory and practice, while fostering problem solving skills, critical thinking skills and quality education. Hence, building a systematic and sustainable model for integrating digital innovation like AI can ensure holistic reform and excellence in basic education in Nigeria.

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THE ROLE OF ARTIFICIAL INTELLIGENCE ON TRANSFORMING SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS (STEM) EDUCATION IN TERTIARY INSTITUTIONS

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Abstract

The fast-growing accessibility and capability of today's educational development, couple with the global scientific and technological trends has given rise to the need for designing or implementing innovative strategies for effective teaching and learning of Science, Technology, Engineering, and Mathematics (STEM) education. This can best be achieved through the use of Artificial Intelligence (AI). AI is the simulation of human intelligence processes by machines, especially computer systems. With AI technology's continuous evolution and popularity, the possibilities for its application in STEM education are promising but not without challenges. AI has the capability to transform the way STEM education is taught and learned. One of the most compelling applications of AI in STEM education is its ability to simulate scientific and technological experiments and provide virtual laboratory experiences to learners. The paper will address the concepts science, technology, engineering, mathematics and AI. The importance of STEM education. The role of AI on STEM education. The challenges in the application of AI on STEM education. Suggested solutions on the challenges in the application of AI on STEM education. In conclusion, the paper recommended among others that staff and students should be adequately trained on the use of AI tools for effective teaching and learning STEM education.

Keywords: Role, AI, Transforming, STEM education.

Introduction

Artificial intelligence (AI) is a field of science concerned with building computers and machines that can reason, learn, and act in such a way that would normally require human intelligence or that involves data whose scale exceeds what humans can analyze. It is the simulation of human intelligence processes by machines, especially computer systems (Hermansyah, *et al.* (2023). Though AI has flourished in numerous domains within the education system, a comprehensive analysis of its role, advantages, and challenges in Science, Technology, Engineering, and Mathematics (STEM) education must be further explored.

Artificial Intelligence in education (AIEd) is an evolving interdisciplinary arena incorporating AI technologies to renovate and enhance teaching and learning environments. Particularly, the application of AI in STEM teaching and learning is becoming more popular, even as interest in AI's effects on general education is growing (Chiu et al., 2023; Gonzalez et al., 2017). Popenici and Kerr (2017) conducted a study to investigate the impact of AI on the teaching-learning process in higher education settings. Their study focused on how intelligent technologies are affecting student learning and traditional teaching approaches in education. Their research presents valuable insights into the incorporation of AI within STEM education contexts. Zawacki-Richter et al.

(2019), in their systematic assessment of AI application in higher education, focused on the vital role that teachers can play in this domain. The results suggest how important it is to explore and understand the needs and perceptions of teachers when integrating these technologies into teaching-learning settings.

The Concept and Importance of STEM Education

Science is a tool that leads to advancement in technology which enhances societal development. The level of scientific exposure, involvement and knowledge of any nation will determine their level of growth economically, technologically, socially and globally. Therefore, science as the driving force for societal development should be studied in schools. Tang and Cooper, (2024) defined science as an area of study that is necessary for development because of its linkage to technology and industry. This definition argued that the knowledge of science brings about technology and industrial development. Science as a systematic enterprise that builds and organized knowledge in form of testable explanations and predictions about the universe. This view justifies the fact that science revolves about organization of knowledge, in terms of giving clear focus on activities in the universe which can come in terms of acquisition of a particular knowledge or teaching. With the studying of science, the pursuit of knowledge and understanding of the natural and social world can be achieved by following a systematic methodology based on evidences. Therefore, science can be seen as the study of natural environment.

The importance of science in the society cannot be over emphasized. The knowledge of science helps to equip the students with problem solving skills to compete with the larger world and solve personal and problem and that of the society at large. Science is essential for quality life, the sustainable development of the planet, and peaceful coexistence among peoples. From the immediate basic essentials of life such as access to water, food and shelter, to other issues such as management of agricultural production, water resources, health, energy resources, biodiversity, conservation, the environment, transport, communication, science provides the basis for action at local, regional, national and transnational levels. The knowledge of science and its associated skills cannot be achieved without science education.

Science education is teaching and learning of science to non-scientists, such as school children, college students or adults within the general public. It is the study of the interrelationship between science as a discipline and the application of educational principles to its understanding in teaching and learning. Mavroudi et al. (2018) opined that science education aims at helping individual learner to gain a functional understanding of scientific concepts and principles that linked with real life situations and acquire scientific skills, attitudes and values necessary to analyze and solve day-to-day problems. There is need to inculcate these knowledge, values and skills in the younger generation at the college level of education in order to make them independent, more knowledgeable and productive members of the society for healthy living. In Colleges of Education, Polytechnics, and Universities in Nigeria, science education is taught as Chemistry Education, Physics Education, Biology Education, Physical and Health Education, Mathematics Education, Computer Science Education, and Integrated Science Education among others.

Technology is the application of scientific knowledge to the practical aims of human life. The word technology is a combination of the Greek *techne*, which means “art, craft,” and *logos*, which means “word, speech.” It is the application of knowledge to develop tools and processes to simplify

tasks. It includes both digital tools like smartphones as well as non-digital tools like pencils (Ibanez, & Delgado-Kloos, 2018).

There are several types of technology that can serve human purposes. Among these are mechanical technology (e.g. wheels, engines), electrical technology (e.g. computer, circuits), communication technology (phones, internet), medical technology (e.g. diagnostics, pharmaceuticals), industrial/manufacturing technology (large-scale production), energy technology (solar, wind), and transportation technology (e.g. vehicles, GPS).

Technology education is the study of technology, in which students learn about the processes and knowledge related to technology. As a field of study, it covers the human's ability to shape and change the physical world to meet needs, by manipulating materials and tools with techniques. In Colleges of Education, Polytechnics and Universities, technology is being taught as technical education (wood work, building, metal), ed. Tech. or tech ed. The courses are designed to teach students to be prepared for vocational and classroom. Technology education involves a broad spectrum of knowledge and activities. It combines knowledge of content, process and skills.

The importance of technology in education cannot be over emphasized. This is because, technology helps personalised learning, enhances learning, improve teaching productivity, access to information and resources, create an engaging learning experience, provide remote learning opportunities, increased accessibility to education, enhance innovative and creativity, collaboration and communication, and makes learning more fun to both teachers and learners..

Engineering is the branch of science and technology concerned with the design, building, and use of engines, machines, and structures. It is the science of solving technical problems and developing new technology and infrastructure (Kafyulilo, Fisser, & Voogt, 2015). Engineering apply the principles of science and mathematics to solve problems, building products, and make processes more efficient.

Engineering education is the activity of teaching knowledge and principles to the professional practice of engineering. It is the instruction of basic sciences. Mathematics, humanities, and other studies that are necessary for engineering practice. In polytechnics and universities, engineering education is taught as civil engineering, electrical engineering, computer science engineering, construction engineering, chemical engineering among others.

Engineering graduates learn to integrate scientific and engineering principles to develop products and processes that contribute to economic growth, advances in medical care, enhanced national security systems, ecologically sound resource management, and many other beneficial areas.

Mathematics is the science and study of quality, structure, space, and change. Mathematics seek out patterns, formulate new conjectures, and establish truth by rigorous deduction from appropriately chosen axioms and definitions. It is the science of structure, order, and relation that has evolved from elemental practices of counting, measuring, and describing the shapes of objects. It deals with logical reasoning and quantitative calculation, and its development has involved an increasing degree of idealization and abstraction of its subject matter. Since the 17th century, mathematics has been an indispensable adjunct to the physical sciences and technology, and in more recent times it has assumed a similar role in the quantitative aspects of the life sciences.

The concepts, theories and formulas in mathematics have huge applications in real-life. To find solutions for various problems we need to learn the formulas and concepts. Therefore, it is important to learn this subject to understand its various applications and significance. Mathematics simply means to learn or to study or gain knowledge. The theories and concepts given in mathematics help us understand and solve various types of problems in academics as well as in real life situations. Mathematics is a subject of logic. Learning mathematics will help students to grow their problem-solving and logical reasoning skills. Mathematics is a science that developed from the investigation of geometric figures and the computing with numbers. Today, it is usually described as a science that investigates abstract structures that it created itself by logical definitions using logic for their properties and patterns (Dai, 2023).

Relationship between Science, Technology, Engineering, and Mathematics

Mathematics is a fundamental part of science, technology, and engineering. It is a tool used to describe and analyse the world around us. Mathematics is used to create models and solve problems, and it is essential for understanding and making progress in many areas of science, technology, and engineering. Science, technology, and engineering acquire tools of mathematics to observe, describe and predict natural phenomena. Science studies the natural world and relies on mathematics. Technology applies scientific and mathematical principles to develop useful tools and systems.

The Role of Artificial Intelligence in STEM Education

Artificial intelligence (AI) is a broad field encompassing various technologies that have been developed over the past 50 years to enable machines to perform tasks traditionally requiring human intelligence, such as perceiving, reasoning, learning, and interacting. It is a field of science concerned with building computers and machines that can reason, learn, and act in such a way that would normally require human intelligence or that involves data whose scale exceeds what humans can analyze. It is the simulation of human intelligence processes by machines, especially computer systems. With AI technology's continuous evolution and popularity, the possibilities for its application in STEM education are promising but not without challenges. AI has the capability to transform the way STEM is taught and learned. One of the most compelling applications of AI in STEM education is its ability to simulate scientific experiments and provide virtual laboratory experiences to learners. This ensures that students can practice and develop their skills in a safe and controlled environment, potentially saving expenses and offering new opportunities for exploring STEM concepts that may not be feasible in traditional laboratory settings (Wahyoo *et al.*, 2019).

By leveraging AI, educators can also move away from traditional, one-size-fits-all approaches to education and instead provide personalized and interactive learning experiences for students. However, the effectiveness of these personalized learning systems depends heavily on the quality and representativeness of the data they are trained on, which can sometimes introduce biases and perpetual existing inequities. In addition, students can also benefit from immediate feedback and adaptive learning pathways, ensuring that they are able to address any misconceptions or gaps in their understanding of scientific phenomena (Mavroudi *et al.*, 2018). AI can also help STEAM educators track and monitor students' progress more effectively, allowing for targeted interventions and support where necessary. Zawacki-Richter *et al.* (2019), in their assessment of AI applications in higher education, focused on the vital role that teacher can play in this domain.

Their results suggest how important it is to explore and understand the needs and perceptions of teachers when integrating these technologies into teaching-learning settings. Moreover, the use of AI can enable the development of interactive and immersive learning environments, making STEM education more engaging and accessible to students with diverse learning styles and needs (Park, *et al.* 2023). As AI continues to advance, the potential for its integration into STEM learning is likely to grow, presenting exciting opportunities to transform and elevate STEM education experiences for students at all levels.

The relevance of AI became very prominent when universities and schools were locked down due to the pandemic of coronavirus outbreak of 2019. Mahmoud (2020) study reported that AI played diverse imminent roles in education particularly STEM education. When AI is incorporated into the teaching and learning system, it creates chances for improvement in the educational section in terms of teachers' teaching and students' learning outcomes. Students learn in their space and individually by receiving personalized tutoring. Concepts that are ordinarily abstract can be presented in a form that will be understood by students, educators identify learning disabilities, and students get feedback on their progress as they progress in the study. When AI is utilized during teaching and learning, especially in the form of cobots, enhanced learning experiences of students are fostered (Zhao, He, & Krajcik, 2022). Teaching with AI assists facilitators to save time as AI answers' students' non-complex, repeated questions via online discussion forums, and as such, teachers redirect the time saved to works of higher value. The knowledge of learners' performance, progression, and potential are decoded by their clickstream data when AI is utilized in teaching and learning.

Another significant advantage is the improvement of exploratory learning through virtual labs and reenactments. AI-powered instruments have the potential to recreate complex logical tests, which may be illogical or hazardous to conduct in a conventional classroom setting (Mahmoud, 2020). These virtual situations offer hands-on learning encounters and permit understudies to try distinctive scenarios, improving their understanding of STEM concepts. This approach was not as supportive of extending understudy engagement but too valuable to democratize access to high-quality STEM instruction. This interconnecting also permits integrating differing datasets into the educational modules, uncovering understudies to real-world logical challenges and datasets (Holmes *et al.*, 2023).

Over the last decades, researchers have examined the use of AI in teaching and learning STEM education for different purposes. For instance, quite a few researchers examined the use of AI applications such as intelligent tutoring systems, virtual reality, and teaching evaluation (Parsia *et al.*, 2020), as well as the use of more general pedagogical methods (e.g. game-based learning, collaborative learning) in teaching and learning in various contexts and disciplines in STEM education (Zawacki-Richter *et al.*, 2019).

The following are common examples of AI that can be used in teaching STEM education in tertiary institutions:

1. Intelligence tutoring system: This is software used in education that has a part of AI incorporated into it. Learners' academic process pathway in terms of their assignment, readjustment in feedback and provide directions as the learning goes on. The software gets

information on the student as the student progresses with it and can deduce the learners' level of competence or incompetence.

2. **Teaching robots:** Teaching robots include every robot that is utilized for the sole purpose of teaching and learning. When robots are used as tools, they are either utilized as a teaching tool for learners or used as an avenue to transmit knowledge as the robots are manipulated.
3. **Learning analytics dashboards:** An application that indicates learners' online conduct patterns in a virtually simulated instructional environment is termed a learning analytics dashboard. Learners' log files are monitored by use of helping tools and digging large quantities of data to discover meaning by having a mental image of the results that will aid understanding from a surface view.
4. **Adaptive learning system:** These are technologies that are capable of adjusting to the course contents and the learners' ability. The purpose is to improve students' learning outcomes in both teachers' instruction and machine learning.
5. **Virtual reality (VR):** When AI is built into a very high-end computer, teaching can be done with it by evolving simulation and interface through numerous sensorial channels. These sensorial modalities involve the senses of sight, hearing, smell, feeling aural, and others. Virtual reality (VR) tools available for usage in the teaching of STEAM are Labster Virtual and PhET simulation.

Factors Militating against the Application of AI in STEM Education.

The Nigerian education system has suffered a lot of setbacks. A beautiful curriculum will be designed but it will crash at the point of implementation. The incorporating of AI into teaching and learning of STEM education will be capable of enhancing students' performance. However, some notable factors militates against the application of AI in teaching and learning of STEM education according to research. Studies on the investigation of factors affecting teachers' adoption of AI in STEM education abound but with the divergent reasons. Lack of AI resources as a factor affects the use of AI (Pima, 2019). The heavy workload of teachers does not give them enough time to explore AI (Hong, Dou, & Chen, 2022). Teachers are not trained and do not have the technical support required to use AI (Alharbi, Elfeky, & Ahmed, 2022). Teachers find AI very difficult to use and so do not adopt it (Mahmoud, (2020)). Computer self-efficacy affects teachers' use of AI (Chiu, et al., 2023). When teachers lack the basic knowledge of the availability and usage of AI-based teaching methods, it can affect their adoption (Gonzalez, et al., 2017). According to United Nations Educational Scientific and Cultural Organization (UNESCO, 2021) emphasized that the successful deployment of AI in education depends on foundational infrastructure and human capacity. In addition, ethical concerns such as data privacy and algorithmic bias were noted, echoing global concerns about the safe and responsible use of AI in schools. Resistance to change especially among older educators who are less digital literate and scepticism and fear of job displacement could hinder AI adoption (Baker & Smith, 2019).

Addressing these challenges requires strategic curriculum redesign, teacher training initiatives, and the implementation of ethical AI policies to ensure fairness and transparency. In addition, efforts to bridge the digital divide and foster industrial-academia collaborations can enhance AI education, providing students with real-world applications and career opportunities. According to

Organization for Economic Co-operation and Development (2020), digital transformation in education must be supported by inclusive policy frameworks to ensure equitable access.

Conclusion

In conclusion, the integration of AI into STEM education will help transform traditional learning methods, offering new opportunities for personalised and adaptive instruction. AI powered tools enhanced learning experiences by tailoring content to individual students, facilitating interactive simulations, and fostering critical thinking, creativity, and problem-solving skills. As AI-driven technologies continue to evolve, their application in STEM education supports interdisciplinary learning, enabling students to develop essential 21st-century skills. However, despite these advantages, the integration of AI in STEM education presents several challenges, including ethical concerns, biases in AI algorithms, teacher preparedness, and unequal access to AI-driven resources.

Recommendations

The paper recommends the following

- i. Artificial intelligence should be enshrined in the curriculum of tertiary institutions (Colleges of Education, Polytechnics, and Universities) irrespective of subject areas.
- ii. Teachers who are directly involved in implementing the curriculum should be taught how to source and apply AI tools for teaching, research, content delivery and others related purposes for using AI on teaching and learning.
- iii. Students need to be taught how to use AI. Therefore, AI should be taught as a general course for all students.
- iv. There should be sufficient and functional resources/infrastructures for effective adoption of AI in schools.
- v. There should be technicians in schools capable of handling AI tools and challenges.
- vi. There should be efficient power supply in schools for effective utilization of AI.

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ARTIFICIAL INTELLIGENCE INTEGRATION IN STEM INSTRUCTION IN SENIOR SECONDARY SCHOOLS: OPPORTUNITIES AND CHALLENGES

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Abstract

Artificial Intelligence (AI) has emerged as a transformative force in education, offering innovative tools that enhance teaching, learning, and assessment processes, particularly in STEM (Science, Technology, Engineering, and Mathematics) education. This paper reviews existing literature on science teachers' perceptions of AI integration in STEM instruction at the senior secondary school level. It examines how teachers' awareness, attitudes, and perceived ease of use influence AI adoption in classroom practices. The review further explores the opportunities and challenges of integrating AI-driven technologies such as intelligent tutoring systems, adaptive learning platforms, and automated assessment tools within STEM classrooms. Findings from reviewed studies indicate that while science teachers generally recognize the potential of AI in improving instructional quality and student engagement, barriers such as inadequate training, limited infrastructure, and low awareness hinder effective adoption. The paper concludes that AI has the potential to transform STEM teaching and learning when adoption is guided by positive teacher perception, supported by robust infrastructure, ongoing professional development, and coherent policy frameworks. It was recommended that capacity building, curriculum redesign, and policy interventions need to be address to enhance AI readiness among science teachers and foster a more technologically responsive STEM education ecosystem.

Keywords: Artificial Intelligence, STEM Education, Science Teachers, Perception, Technology Integration, Secondary Schools, Educational Innovation

Introduction

Artificial Intelligence (AI) is increasingly transforming educational systems worldwide, particularly in how STEM (Science, Technology, Engineering, Mathematics) subjects are taught and learned. AI applications such as adaptive tutoring systems, virtual laboratories, and automated assessment tools offer possibilities for tailoring instruction, increasing student engagement, and providing real-time feedback (Rocconi, 2025; Wang *et al.*, 2025). This global trend emphasizes an urgent need for AI literacy within educational ecosystems not only among students but crucially among teachers responsible for integrating these technologies into STEM pedagogy (Wang *et al.*, 2025; Usman, 2025).

Despite the promise, a persistent gap exists between AI's theoretical benefits and its practical uptake in secondary school settings. For instance, a study in Lagos State found that although secondary school teachers were generally aware of AI, most lacked deep understanding of how AI works and were uncertain about using AI in instruction (Adekemi *et al.*, 2024). In many cases, barriers such as insufficient training, poor infrastructure, and policy incoherence impede adoption (Embracing the future of Artificial Intelligence in the classroom, 2024). These challenges are often

more severe in under-resourced regions in Sub-Saharan Africa, where the disconnect between policy vision and classroom reality is stark (UNESCO, 2023).

In the Nigerian education context, evidence also suggests that the use of AI in secondary education remains limited. In Akwa Ibom State, for example, a descriptive/ correlational study revealed that although teachers acknowledge the potential of AI tools, their actual integration into classroom instruction is low, hindered by constraints such as limited ICT infrastructure and lack of institutional support (Imoh, Bassey, Essien, Udoh, and Ekarika, 2025). Closer to home in Kwara and Ilorin, a recent study in *Ilorin Journal of Education* assessed educators' awareness and adoption of AI tools for "edupreneurship" and reported low awareness and adoption levels, highlighting that many educators are unfamiliar with available AI tools and their pedagogical applications (Asiyanbola, 2025).

Understanding teachers' perceptions of AI integration is therefore critical. Under models like the Technology Acceptance Model (TAM), perceptions especially perceived usability and ease of use are central determinants of whether teachers adopt new technologies (Mah and Groß, 2024). In Nigeria, research on pre-service teachers shows that basic knowledge of AI and social norms are significant predictors of intention to learn and use AI (Investigating pre-service teachers' AI perception, 2024). Teachers' beliefs about AI's usefulness, their comfort with the technology, and their perceived readiness influence whether AI tools are adopted in practice or remain idle.

Against this backdrop, the objectives of this review are threefold: (a) to examine how science teachers perceive AI integration in STEM instruction, including both perceived benefits and reservations; (b) to identify key influencing factors such as awareness, training, infrastructure, and institutional support; and (c) to surface opportunities and challenges of AI in STEM teaching as documented in recent literature (2020–2025).

This inquiry is significant because teachers are the gatekeepers of educational innovation. Even the most advanced AI tools will have limited impact if teachers lack trust in them, do not understand them, or feel incapable of using them (Mah and Groß, 2024). In senior secondary schools where students are preparing for higher education and STEM-related careers the depth and fidelity of AI integration can profoundly shape learning experiences. This review focuses on literature from 2020 to 2025 to capture recent advancements in AI, educational technology policy, and teacher development in Nigeria and beyond. By integrating both global and local studies, the review aims to highlight contemporary opportunities (for instance, generative AI, AI-assisted labs) and challenges (for instance, algorithmic bias, equity issues) relevant to the Nigerian secondary school context. In the sections that follow, the paper first conceptualizes AI and STEM instruction, then reviews theoretical frameworks for technology adoption, synthesizes empirical and conceptual studies on teachers' perceptions, discusses opportunities and barriers, and finally offers implications and recommendations for policy, practice, and future research.

Understanding Artificial Intelligence in Education

Artificial Intelligence (AI) in education often referred to as AIEd denotes computational systems that exhibit human-like cognitive functions, such as learning, adapting, self-correction, pattern recognition, and decision-making, typically through data processing and algorithmic models (Popenici *et al.*, 2023; Gu and Ericson, 2025). In educational contexts, AI encompasses intelligent

tutoring systems, learning analytics, automated grading, adaptive instructional content, virtual and augmented reality systems, and conversational agents/chatbots, among others (Gu and Ericson, 2025; Tahir, Hassan, and Shagoo, 2024). These systems are designed to augment or support human educators by providing personalized feedback, automating routine tasks, and enabling insights into student learning processes that would otherwise be difficult to capture in traditional settings (Stanford SCALE Initiative, Chen, Chen and Lin, 2020; Smart Learning Environments, 2025). As AI technologies become more sophisticated, issues such as explainability, bias, ethical use, and data privacy have become central to discussions about their role in education (Altukhi and Pradhan, 2025).

AI in STEM Education

Artificial Intelligence (AI) has become an increasingly powerful enabler of innovation in STEM (Science, Technology, Engineering, and Mathematics) education, transforming the way teachers design, deliver, and assess learning. AI tools such as adaptive tutoring systems, intelligent simulations, and predictive analytics platforms enhance instructional personalization and deepen conceptual engagement (Gu and Ericson, 2025). Adaptive Intelligent Tutoring Systems (ITS), for instance, dynamically adjust instructional sequences, difficulty levels, and feedback mechanisms to individual students' learning trajectories, thereby improving mastery and motivation in subjects like mathematics and physics (Rocconi, 2025). Similarly, AI-powered virtual laboratories and modeling environments provide authentic opportunities for experimentation and inquiry allowing students to visualize abstract scientific phenomena, perform risk-free experiments, and cultivate data analysis skills critical to STEM learning (Tahir *et al.*, 2024). These systems reduce dependence on physical resources and democratize access to high-quality laboratory experiences, particularly in resource-constrained contexts such as secondary schools in Sub-Saharan Africa (UNESCO, 2023).

Moreover, AI-driven data analytics and assessment tools enable a paradigm shift toward evidence-based and responsive teaching. Through continuous monitoring of student interaction data, learning analytics systems identify misconceptions, measure engagement, and provide actionable insights for teachers to adapt instruction in real time (Mah and Groß, 2024). Research also highlights AI's potential to facilitate formative assessment, improve feedback quality, and support differentiated instruction across diverse learner profiles (Altukhi and Pradhan, 2025). In science classrooms, AI-based diagnostic systems can detect patterns of misunderstanding in topics such as chemical equilibrium or Newtonian mechanics, providing personalized scaffolds for remediation (Alieto *et al.*, 2023). However, while teachers generally perceive AI as a valuable supplement to inquiry-based learning, challenges persist regarding digital competence, infrastructure, and pedagogical readiness factors that determine the depth and sustainability of AI integration in STEM instruction (Asiyanbola, 2025; Imoh *et al.*, 2025).

Theoretical Underpinnings

The integration of Artificial Intelligence (AI) into STEM education is best understood through theoretical frameworks that explain technology adoption behaviors among educators. Two prominent models that guide such analysis are the Technology Acceptance Model (TAM) and the Diffusion of Innovation (DOI) theory. These frameworks help clarify how teachers' beliefs, attitudes, and social contexts influence their willingness to embrace emerging technologies such as AI (Mah and Groß, 2024; Gu and Ericson, 2025).

The **Technology Acceptance Model (TAM)**, introduced by Davis (1989), posits that two primary determinants **Perceived Usefulness (PU)** and **Perceived Ease of Use (PEOU)** shape an individual's behavioral intention to adopt and use a technology. In educational settings, TAM has been extensively applied to explain teachers' adoption of digital tools, including AI-based learning platforms (Al Darayseh and Mersin, 2025; Gu and Ericson, 2025). When educators perceive AI technologies as beneficial for improving instructional effectiveness (high PU) and as user-friendly and easy to learn (high PEOU), their likelihood of integration increases (Akinola, 2023). Conversely, adoption tends to stagnate where AI systems are seen as opaque, technically demanding, or misaligned with existing pedagogical routines (Tahir et al., 2024). Contemporary extensions of TAM, such as the Unified Theory of Acceptance and Use of Technology (UTAUT), have reinforced the significance of factors like social influence and facilitating conditions in shaping AI adoption behaviors among teachers (Viberg, Wasson, and Mikroyannidis, 2023).

Complementing TAM, Rogers' Diffusion of Innovation (DOI) theory (2003) explains how innovations spread through social systems over time, based on five key characteristics: relative advantage, compatibility, complexity, trialability, and observability. In the context of STEM education, these elements play crucial roles in determining how quickly and extensively AI tools are adopted (Preparing High School Teachers to Integrate AI Methods into STEM Classrooms, 2023). Teachers are more likely to adopt AI technologies when they perceive clear instructional advantages (relative advantage), alignment with their pedagogical goals (compatibility), manageable technical demands (low complexity), opportunities for experimentation (trialability), and visible evidence of success in peer classrooms (observability) (Means, 2013; Khong, 2023). Research shows that when teachers observe peers successfully implementing AI-driven instructional modules and witnessing positive student engagement, their confidence and adoption intentions increase (Mah and Groß, 2024; Imoh et al., 2025).

Together, TAM and DOI offer complementary perspectives: TAM provides insights into the individual cognitive and perceptual factors influencing teachers' acceptance of AI, while DOI illuminates the social diffusion processes governing how these innovations propagate across educational institutions. Integrating these frameworks allows for a nuanced understanding of how science teachers' perceptions, institutional context, and peer dynamics collectively shape the adoption of AI in STEM education (Gu and Ericson, 2025; Tahir et al., 2024). Their combined application provides a robust theoretical basis for designing interventions and professional development programs that foster sustained and meaningful AI integration in schools.

Teachers' Perception in Technology Adoption

Teachers' perceptions play a decisive role in the successful adoption and pedagogical integration of emerging technologies such as Artificial Intelligence (AI). In educational innovation, perception often acts as the first filter through which teachers interpret the usefulness, usability, and legitimacy of new tools (Mah and Groß, 2024). According to the Technology Acceptance Model (TAM), teachers' perceived usefulness (PU) the belief that AI will enhance teaching effectiveness and perceived ease of use (PEOU) the belief that AI systems can be learned and operated without excessive effort are critical predictors of actual adoption (Viberg, Wasson, and Mikroyannidis, 2023). Teachers who perceive AI as compatible with their instructional practices, capable of improving learning outcomes, and aligned with curriculum goals are more willing to integrate it

into their classrooms (Gu and Ericson, 2025). Conversely, when teachers perceive AI as complex, time-consuming, or unreliable, resistance tends to increase, even when institutional support is available (Rocconi, 2025; Tahir, Hassan, and Shagoo, 2024).

Perception is also shaped by teachers' prior experiences, technological self-efficacy, and contextual conditions, such as access to infrastructure, professional development, and administrative encouragement (Imoh, Bassey, Essien, Udoh, and Ekarika, 2025; Asiyabola, 2025). For instance, studies in Nigerian secondary schools reveal that teachers' readiness to adopt AI technologies is positively influenced by exposure to ICT tools, prior digital training, and the perceived institutional culture supporting innovation (Adekemi et al., 2024). Teachers with limited ICT competence or negative prior experiences with educational technology often view AI as a threat to their professional identity or as an impractical innovation (Viberg et al., 2023). Moreover, the socio-cultural and ethical implications of AI such as concerns about job displacement, data privacy, and algorithmic bias further influence teachers' affective and cognitive responses to adoption (Altukhi and Pradhan, 2025; UNESCO, 2023).

In STEM contexts, positive teacher perceptions are essential because AI-mediated instruction demands not only technical fluency but also pedagogical adaptability. Teachers who view AI as a collaborative partner rather than a replacement tend to experiment more confidently with adaptive tutoring systems, simulation platforms, and intelligent assessment tools (Johnson and Lamb, 2015). Therefore, fostering favorable perceptions requires ongoing professional development, peer collaboration, and institutional policies that demystify AI and position it as an ally in enhancing scientific inquiry, creativity, and problem-solving skills among students (Mah and Groß, 2024; Gu and Ericson, 2025).

Perspectives on AI Integration in STEM

The global movement toward integrating Artificial Intelligence (AI) in STEM education reflects a paradigm shift in instructional design, pedagogy, and teacher competence. Across the world, educational systems are exploring AI's potential to enhance personalized learning, foster critical thinking, and improve assessment efficiency (Gu and Ericson, 2025; Wang et al., 2025). However, the extent to which AI is effectively embedded in science teaching varies widely between developed and developing nations, largely due to disparities in teacher readiness, infrastructure, and policy frameworks (UNESCO, 2023; Imoh *et al.*, 2025). Understanding these global and regional perspectives is essential for contextualizing science teachers' perceptions of AI integration within Nigerian secondary schools.

Global Perspectives on AI Integration in STEM

Globally, the use of AI in STEM education has expanded rapidly, driven by technological innovation and post-pandemic investments in digital learning ecosystems (Mah and Groß, 2024). In developed nations such as the United States, Finland, and South Korea, AI-powered adaptive systems, robotics, and intelligent laboratories are increasingly employed to support inquiry-based and project-based learning in science and mathematics classrooms (Rocconi, 2025; Viberg *et al.*, 2023). Studies indicate that teachers in these contexts generally demonstrate high awareness of AI tools and moderate-to-strong confidence in integrating them for instructional purposes (Igwe, 2020). Moreover, professional development programs in the U.S. and Europe have focused on building "AI literacy" among teachers emphasizing ethical awareness, algorithmic thinking, and the pedagogical affordances of AI (Gu and Ericson, 2025; Wang *et al.*, 2025).

However, even in technologically advanced regions, teachers express concerns about data privacy, loss of professional autonomy, and the ethical implications of AI-assisted assessment (Altukhi and Pradhan, 2025). In addition, the adoption of AI tools is uneven across subject areas, with science and mathematics teachers being early adopters, while humanities teachers often exhibit greater skepticism (Mah and Groß, 2024). These findings suggest that while access and awareness are necessary conditions for AI integration, positive teacher perception and systemic support remain critical for sustainability.

AI Integration in African and Nigerian Contexts

In Africa, the integration of AI in education remains nascent but rapidly evolving. UNESCO (2023) highlights that AI adoption across Sub-Saharan Africa is constrained by infrastructural deficits, limited teacher training, and policy fragmentation. Nevertheless, pilot projects in South Africa, Kenya, and Rwanda demonstrate growing interest in using AI-powered platforms for science simulation, assessment, and adaptive learning (UNESCO, 2023; Mbogo and Mwangangi, 2024). Teachers' perceptions across these countries generally reflect optimism about AI's potential to enhance STEM learning but also apprehension due to technical and resource challenges (Okonkwo, 2024).

In Nigeria, emerging evidence reveals a mixed pattern of perception and readiness. Studies in Akwa Ibom and Kwara States report that while science teachers acknowledge AI's potential to improve STEM teaching, actual classroom integration remains low due to limited awareness, inadequate ICT skills, and lack of institutional support (Imoh et al., 2025; Asiyanbola, 2025). Similarly, Adekemi et al. (2024) found that many Nigerian secondary school teachers are aware of AI tools in theory but lack practical exposure and confidence in their use. The gap between teachers' perceived usefulness of AI and their actual usage underscores the need for targeted professional development and supportive policies. As Nigeria continues to align its education sector with global digital transformation trends, understanding and addressing these perceptual barriers is essential for sustainable AI adoption in STEM instruction.

Factors Influencing Science Teachers' Perception of AI

Teachers' perceptions of AI in STEM education are shaped by a complex interplay of personal, institutional, and contextual factors.

Awareness and Exposure: Teachers' awareness of AI's capabilities strongly influences their perception of its educational value. Teachers with higher exposure to AI technologies through workshops, online platforms, or demonstration projects tend to perceive AI more positively (Rocconi, 2025; Gu and Ericson, 2025). Conversely, limited exposure fosters skepticism and misunderstanding about AI's relevance to classroom practice (Asiyanbola, 2025).

Training and Professional Development: Professional development remains the most significant enabler of AI adoption. Studies show that targeted training programs enhance teachers' technological self-efficacy, reduce anxiety, and promote experimentation with AI-based instructional tools (Mah and Groß, 2024; Wang et al., 2025). In Nigeria, most teachers report inadequate or nonexistent training opportunities in AI pedagogy (Imoh *et al.*, 2025).

Infrastructure and Access: Access to reliable internet, hardware, and electricity remains a persistent barrier in many developing contexts (UNESCO, 2023). Without adequate infrastructure, even teachers with positive perceptions struggle to integrate AI tools effectively.

Administrative and Policy Support: Supportive leadership and clear institutional policies facilitate technology diffusion by legitimizing innovation and providing material resources (Mbogo and Mwangangi, 2024). Lack of administrative endorsement often leaves teachers isolated in their attempts to adopt AI.

Perceived Ease of Use and Usefulness: Consistent with the Technology Acceptance Model, teachers' perceptions of AI's usefulness and ease of use predict adoption levels (Viberg et al., 2023). Where AI is seen as user-friendly and directly beneficial to learning outcomes, adoption is more likely to occur.

Collectively, these factors underscore that teacher perception is both a personal and systemic phenomenon shaped not only by beliefs and attitudes but also by environmental and institutional realities.

Opportunities and Benefits of AI in STEM Instruction

Artificial Intelligence (AI) holds immense promise for transforming the pedagogy of Science, Technology, Engineering, and Mathematics (STEM) education. It offers tools and systems that enhance instructional delivery, personalize learning, streamline assessment, and enable innovative inquiry-based approaches.

Enhancing Instructional Delivery

AI-driven instructional systems have revolutionized how science and mathematics content is delivered. Intelligent Tutoring Systems (ITS) and adaptive learning platforms such as ALEKS and Carnegie Learning's MATHia dynamically adjust content based on individual learner performance, providing immediate feedback and scaffolding (Jones, 2021). These tools enable science teachers to deliver differentiated instruction efficiently, addressing varying levels of student mastery within the same classroom (Mah and Groß, 2024).

Moreover, AI-powered teaching assistants such as chatbots and virtual agents can supplement teachers by answering student queries, explaining scientific concepts, and managing repetitive instructional tasks (Wang *et al.*, 2025). This not only increases instructional efficiency but also allows teachers to focus on higher-order learning objectives such as inquiry, experimentation, and conceptual understanding. Rocconi (2025) observed that teachers who integrate AI-driven platforms report improvements in student engagement, conceptual retention, and classroom participation. As such, AI tools are increasingly viewed not as replacements for teachers but as co-instructors that enhance pedagogical delivery and flexibility.

Promoting Personalized Learning

One of AI's most celebrated benefits in STEM education is its capacity for personalization. AI-based learning systems use algorithms to analyze individual student data, learning preferences, and cognitive patterns to create customized learning paths (Gu and Ericson, 2025). This personalization ensures that students progress at their own pace while receiving targeted

remediation or enrichment activities where necessary (Viberg, Wasson, and Mikroyannidis, 2023). In science subjects, personalized learning can significantly enhance students' conceptual understanding by allowing repeated practice, scaffolded problem-solving, and feedback aligned with individual misconceptions (Tahir *et al.*, 2024). Furthermore, adaptive AI dashboards enable teachers to track student performance in real time, enabling early interventions before misconceptions become entrenched (Graham, 2020). Through this process, AI supports a more inclusive learning environment where high-achieving and struggling students alike receive tailored instructional support.

Improving Assessment and Feedback

AI-driven assessment tools are transforming how teachers evaluate student learning in STEM education. Automated grading systems, intelligent essay scoring, and performance analytics allow for rapid, consistent, and objective evaluation of student work (Altukhi and Pradhan, 2025). These systems not only save teachers valuable time but also provide rich data visualizations on student strengths, weaknesses, and learning trajectories (Mah and Groß, 2024). In science education, formative assessments supported by AI such as diagnostic quizzes and interactive simulations generate real-time feedback that enhances students' self-regulation and metacognitive awareness (Rocconi, 2025). AI-enabled platforms can detect patterns of misunderstanding (for instance, recurring misconceptions in physics problems) and recommend targeted resources, thereby supporting precision teaching (Viberg *et al.*, 2023). The result is a more efficient, transparent, and responsive assessment ecosystem that fosters continuous learning improvement rather than episodic evaluation.

Supporting Inquiry-Based and Experimental Learning

AI applications in STEM extend beyond knowledge delivery and assessment to support inquiry-based, experiential learning. Virtual laboratories and AI-enabled simulations allow students to engage in scientific experimentation without the limitations of physical lab infrastructure (Hill, 2020; Mbogo and Mwangangi, 2024). These virtual labs replicate real-world scientific phenomena such as chemical reactions, planetary motion, or ecological interactions, promoting deeper conceptual understanding and problem-solving abilities (Tahir *et al.*, 2024).

In resource-constrained settings, such as many Nigerian schools, AI-enabled virtual environments can serve as cost-effective alternatives to traditional laboratories (Asiyanbola, 2025). By supporting experimentation, hypothesis testing, and reflection, AI-powered simulations enhance students' inquiry skills core competencies in STEM education. Teachers also benefit, as such systems provide automated monitoring, allowing them to observe student progress and intervene when necessary (Gu and Ericson, 2025). Hence, AI strengthens inquiry-based pedagogy by merging experiential learning with intelligent feedback systems.

Challenges in AI Integration

Despite its transformative potential, the integration of Artificial Intelligence (AI) in STEM instruction faces multiple challenges, particularly in developing educational contexts such as Nigeria and Sub-Saharan Africa. Research indicates that while teachers recognize AI's pedagogical value, practical, infrastructural, and ethical barriers hinder widespread adoption (Imoh *et al.*, 2025; UNESCO, 2023). The following subsections outline the major constraints affecting the adoption and sustainable use of AI in STEM education.

Lack of Technical Skills and Training

A significant challenge to AI integration in STEM classrooms is the limited technical competence of teachers. Many science teachers lack the necessary knowledge to operate AI tools or interpret their analytical outputs (Adekemi *et al.*, 2024). Inadequate professional development programs have left educators underprepared to integrate AI into teaching and assessment effectively (Rocconi, 2025).

According to Mah and Groß (2024), professional development remains the strongest predictor of teachers' confidence and willingness to use AI systems. However, in Nigeria and other developing contexts, such opportunities are rare or poorly structured, leading to persistent skill gaps (Asiyanbola, 2025). This lack of capacity not only delays adoption but also contributes to misconceptions about AI as overly complex or intimidating for classroom use (Viberg *et al.*, 2023).

Limited Infrastructure and Internet Connectivity

Infrastructural limitations remain one of the most pervasive obstacles to AI adoption in education, particularly in Africa. Stable electricity, reliable internet connectivity, and access to modern digital devices are prerequisites for effective AI deployment, yet these remain inadequate in many public schools (UNESCO, 2023).

Studies conducted in Nigeria report that teachers often struggle with outdated computers, limited bandwidth, and intermittent power supply, rendering many AI applications impractical (Imoh *et al.*, 2025; Mbogo and Mwangangi, 2024). Even when AI tools are available, technical support is often lacking, leading to rapid abandonment of innovation projects. Such infrastructural deficiencies create inequities between urban and rural schools, perpetuating a digital divide in STEM education (UNESCO, 2023; Adekemi *et al.*, 2024).

Resistance to Change and Low Perceived Usefulness

Teachers' attitudes and perceptions are critical determinants of AI adoption. Resistance to technological change often stems from low perceived usefulness, anxiety about automation, or skepticism regarding AI's educational relevance (Rocconi, 2025). Within the Technology Acceptance Model framework, teachers are unlikely to use technologies they do not perceive as advantageous or compatible with their teaching practices (Viberg *et al.*, 2023).

In Nigeria, Asiyanbola (2025) observed that many science teachers still prefer traditional instructional methods and express fears that AI may undermine their professional autonomy. Similarly, Tahir *et al.* (2024) found that teachers' mistrust in AI-based systems due to perceived opacity or unpredictability further dampens enthusiasm. Such attitudinal barriers highlight the need for continuous sensitization and exposure to AI's instructional benefits.

Ethical and Data Privacy Concerns

AI integration in education introduces significant ethical and data privacy challenges. Teachers frequently express concerns about how AI systems collect, store, and use student data, fearing breaches of confidentiality or algorithmic bias (Altukhi and Pradhan, 2025). According to Viberg *et al.* (2023), the lack of transparent governance in AI-driven analytics can reduce teacher trust, especially when AI recommendations conflict with teachers' professional judgment. Additionally,

there are ethical concerns regarding student profiling, surveillance, and the reinforcement of social inequities through biased algorithms (UNESCO, 2023). Teachers' awareness of these issues, though still developing, influences their willingness to rely on AI-based assessments and recommendations (Gu and Ericson, 2025). Thus, addressing ethical apprehensions through training, transparency, and clear data protection policies is essential for sustainable AI use in schools.

Policy Gaps and Funding Constraints

Policy incoherence and inadequate funding represent systemic barriers to AI adoption in STEM education. Although several nations, including Nigeria, have introduced digital education frameworks, few have clear, actionable strategies for integrating AI into secondary curricula (UNESCO, 2023). Asiyanbola (2025) notes that AI-related initiatives in Nigerian schools are typically donor-driven or pilot-based rather than embedded in national education policy.

Furthermore, insufficient funding limits the procurement of necessary hardware, maintenance of infrastructure, and support for teacher training (Mbogo and Mwangangi, 2024). Without consistent government commitment and institutional policy alignment, AI integration remains fragmented and unsustainable. Gu and Ericson (2025) emphasize that policy direction must include teacher professional development, ethical guidelines, and research funding to ensure equity and long-term impact.

Implications for Teacher Education and Policy

The integration of Artificial Intelligence (AI) in STEM education requires more than technological adoption; it necessitates strategic reform in teacher education, institutional capacity, and policy frameworks. The reviewed literature underscores that teachers' AI literacy, institutional support mechanisms, and policy coherence are central to effective AI integration (Gu and Ericson, 2025; Mah and Groß, 2024). For nations such as Nigeria, where AI use in schools is still emerging, strengthening teacher preparation and creating supportive policy environments are vital for closing the gap between potential and practice.

Integrating AI Literacy in Teacher Education Programs

AI literacy the ability to understand, evaluate, and use AI tools responsibly should be embedded in teacher education curricula (Gu and Ericson, 2025). Teacher preparation programs must evolve from basic ICT training to comprehensive AI competence, including algorithmic thinking, data interpretation, and ethical awareness (Rocconi, 2025). Such literacy ensures that future STEM teachers can critically assess AI applications and leverage them to support inquiry-based, student-centered instruction (Wang *et al.*, 2025).

Mah and Groß (2024) emphasize that pre-service teacher education should introduce conceptual and practical modules on AI in pedagogy, while in-service programs should reinforce hands-on use of AI tools in classroom contexts. By institutionalizing AI literacy at both pre-service and professional levels, teacher education can produce reflective practitioners capable of adapting to evolving digital pedagogies (Viberg *et al.*, 2023).

Institutional Support and Continuous Professional Development

Sustained AI integration in STEM classrooms requires robust institutional support and continuous professional development (CPD). Institutions must foster environments that encourage experimentation, collaboration, and innovation among teachers (Mah and Groß, 2024). Regular training workshops, mentorship programs, and peer learning networks can enhance teachers' self-efficacy and confidence in applying AI tools (Asiyanbola, 2025).

In developed systems, institutional mechanisms such as AI competence centers and digital learning labs have proven effective in supporting ongoing teacher learning (Hill, 2018; Al Breiki et al., 2023). For Nigerian schools, institutional investment in professional learning communities, supported by educational technology hubs, would enable teachers to remain current with AI advancements (Imoh *et al.*, 2025). Continuous training ensures not only technical proficiency but also pedagogical innovation aligned with AI's transformative potential.

Government and Stakeholder Interventions

Government and stakeholder collaboration is critical for scaling AI adoption in STEM education. National education policies must explicitly recognize AI as a strategic tool for improving instructional quality, assessment, and workforce readiness (UNESCO, 2023). Targeted funding for AI infrastructure, teacher training, and research on local adaptation models is essential (Mbogo and Mwangangi, 2024).

Stakeholders including ministries of education, teacher unions, and private edtech companies should co-develop implementation frameworks that integrate AI ethics, inclusivity, and sustainability principles (Altukhi and Pradhan, 2025). For instance, partnerships between universities and technology firms can facilitate teacher access to AI platforms and localized content (Adekemi et al., 2024). Such multi-stakeholder collaboration ensures alignment between national digital transformation goals and classroom-level realities.

Developing AI-Friendly STEM Curricula

Curricular innovation is central to embedding AI within STEM education. Traditional curricula often emphasize rote learning and procedural tasks, which are misaligned with the analytical, data-driven approaches enabled by AI (Gu and Ericson, 2025). Developing AI-friendly STEM curricula involves integrating computational thinking, problem-based learning, and ethics-driven inquiry into existing syllabi (Tahir *et al.*, 2024).

In this regard, teachers should be empowered to co-design curriculum units that use AI tools for experimentation, modeling, and real-time assessment (Smart Learning Environments, 2025). National curriculum agencies and examination boards must also align learning outcomes with 21st-century skills such as data literacy, algorithmic reasoning, and responsible AI use (UNESCO, 2023). Such reforms will cultivate learners who are not only consumers of AI technology but active creators and innovators in the STEM domain.

Conclusion and Recommendations

The integration of Artificial Intelligence (AI) in STEM instruction presents significant opportunities to enhance teaching, learning, and assessment processes. AI can improve instructional delivery, promote personalized learning, facilitate timely feedback, and support

inquiry-based experimentation, transforming the STEM classroom into a more adaptive and engaging environment. However, the success of AI adoption heavily depends on teachers' perceptions, including their beliefs about its usefulness, ease of use, and relevance to pedagogy. Teachers who view AI positively and feel confident in its application are more likely to integrate it effectively into their instructional practice.

Despite its potential, several challenges hinder widespread AI adoption in STEM education. These include limited technical skills and training, inadequate infrastructure, resistance to change, ethical concerns, and fragmented policy support. Addressing both perceptual and systemic barriers is essential to ensure that AI technologies are used meaningfully and sustainably in secondary school classrooms.

To maximize the benefits of AI in STEM education, the following recommendations are proposed:

1. **Strengthen teachers' AI competencies** through targeted pre-service and in-service training programs that combine technical skills, pedagogical strategies, and ethical awareness.
2. **Improve infrastructure and access to digital tools**, including reliable internet, electricity, and AI-enabled learning platforms, to support equitable implementation.
3. **Foster partnerships between educational institutions and AI developers** to facilitate localized tool development, practical training, and ongoing support networks for teachers.
4. **Encourage policy frameworks** that promote ethical, responsible, and sustainable use of AI in schools, including guidelines on data privacy, equity, and integration into STEM curricula.

In conclusion, AI has the potential to transform STEM teaching and learning when adoption is guided by positive teacher perception, supported by robust infrastructure, ongoing professional development, and coherent policy frameworks. By addressing these factors, education systems can empower science teachers to become effective agents of AI-enabled pedagogy, preparing students for 21st-century STEM challenges and opportunities.

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INTEGRATING ARTIFICIAL INTELLIGENCE INTO METALWORK TECHNOLOGY EDUCATION: A STEM-BASED APPROACH FOR DEVELOPING SKILLED AND INNOVATIVE TECHNICIANS FOR EVOLVING DEMANDS OF INDUSTRY 4.0

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Abstract

The growing influence of Artificial Intelligence (AI) in education and industry has created new opportunities and challenges for industrial Technology Education. In particular, metalwork technology education remains a crucial driver of industrial growth, yet it continues to rely heavily on traditional teaching methods that emphasize routine skills over innovation. This gap limits the capacity of graduates to meet the evolving demands of Industry 4.0, where AI-driven processes and problem-solving competencies are central to workforce relevance. This paper explores the integration of AI into metalwork technology education through a Science, Technology, Engineering, and Mathematics (STEM) framework, with the goal of producing skilled and innovative technicians. The study adopts a conceptual and practice-oriented approach, drawing insights from international case studies, existing literature on AI in technical education, and practical examples from industrial applications of AI in metalwork such as smart welding, predictive maintenance, and AI-assisted design. The paper develops a framework that illustrates how AI-enhanced STEM pedagogy through problem-based learning, digital simulations, design optimization, and project-based tasks can transform metalwork instruction from routine manual skill development to a platform for creativity, critical thinking, and innovation. Findings highlight that AI integration within a STEM framework has the potential to enhance student engagement, improve problem-solving skills, and foster innovation competencies essential for sustainable workforce development. The paper concludes by recommending curriculum reform, teacher retraining, and strategic investment in AI-enabled teaching tools to align technical education with global best practices. Ultimately, the study positions AI-enhanced STEM pedagogy as a catalyst for bridging the gap between traditional metalwork instruction and the skills required in AI-driven industrial environments.

Keywords: Artificial Intelligence, Metalwork Technology, STEM Pedagogy, Workforce Innovation.

Introduction

Artificial Intelligence (AI) is increasingly becoming a central driver of change in education, industry, and society. Across the globe, the integration of AI into Science, Technology, Engineering, and Mathematics (STEM) education is transforming how learners acquire knowledge and develop problem-solving skills. Advanced tools such as adaptive learning platforms, AI-based assessment systems, and intelligent simulations have created more personalized and dynamic learning environments (Abrar *et al.*, 2025). This global trajectory highlights a future where learners not only consume knowledge but actively collaborate with intelligent systems to co-create

solutions making it essential to examine how this trend connects with broader STEM education reforms.

The emphasis on STEM education in recent years reflects its role as a catalyst for equipping students with competencies relevant to Industry 4.0 and beyond. Governments, policy makers, and educational institutions are investing heavily in STEM programs enriched with AI capabilities to ensure that graduates are adaptable, innovative, and technologically literate (Roffia, 2025). In advanced economies, AI-enhanced STEM initiatives have already produced a new generation of learners who are technically proficient while integrating creativity with computational thinking. For developing countries, this momentum offers both a challenge and an opportunity—pointing to the need to contextualize these innovations within practical technical fields such as metalwork.

Within this broader STEM framework, metalwork technology education holds a unique position as a foundation for technical and vocational training. It equips learners with hands-on skills in machining, welding, fabrication, and structural design, which are indispensable to industrial development and infrastructure growth (Umachandran *et al.*, 2019). By fostering precision, discipline, and creativity, metalwork education prepares students to meet the demands of industries such as manufacturing, construction, and automotive engineering. In regions like Nigeria, where unemployment among young graduates remains high, metalwork education extends beyond industrial needs to entrepreneurship, as graduates often establish small-scale enterprises that drive local economies (Venatius *et al.*, 2021). Yet, despite its importance, the discipline continues to face challenges rooted in outdated teaching approaches.

Traditional methods in metalwork technology education often emphasize manual repetition over critical thinking and problem-solving. This has led to a growing mismatch between the skills taught in classrooms and the expectations of industries shaped by automation and digitalization (Goulart *et al.*, 2022). Consequently, graduates may be technically trained but insufficiently prepared for the realities of modern work environments that require adaptive and innovative thinking. These limitations underscore the urgency of transforming pedagogical approaches—an urgency that points directly to the potential benefits of Artificial Intelligence in enriching metalwork instruction. The integration of AI into metalwork education presents opportunities to close existing gaps in skill training and workforce readiness. AI-driven tools such as predictive design software, virtual welding simulators, and intelligent defect detection systems enrich the learning process by making it more interactive, cost-effective, and aligned with real-world practices (Jatavallabhula *et al.*, 2025). Through simulations, learners can refine welding techniques without risks or material wastage, while intelligent tutoring systems provide real-time feedback to accelerate mastery. These innovations not only enhance learning efficiency but also address the resource shortages faced by underfunded technical institutions showing how AI can be a bridge between traditional limitations and modern expectations.

More importantly, embedding AI into metalwork education redefines the role of technicians from routine operators to innovative problem-solvers. Learners who interact with AI-enhanced systems are exposed to creativity, decision-making, and higher-order thinking processes that mirror the demands of Industry 4.0 and 5.0 workplaces (Roffia, 2025). In this way, AI is not merely a tool for technical mastery but also a driver of innovation, preparing graduates to both meet and shape the future of industrial transformation. This alignment underscores that integrating AI into

metalwork is not just an educational enhancement but a strategic necessity for global workforce relevance.

Ultimately, the convergence of AI, STEM education, and metalwork technology represents a necessary evolution in technical education. While global trends highlight the transformative role of AI in teaching and learning, the unique demands of metalwork emphasize why its adoption in this field is urgent. By embedding AI tools into curricula, technical institutions can enhance skill acquisition, foster innovation, and empower learners to thrive in an increasingly technology-driven economy. This synthesis of tradition and technology therefore provides a roadmap for developing skilled and innovative technicians laying the foundation for deeper inquiry in subsequent sections of this paper.

Statement of the Problem

In Nigeria, Technical and Vocational Education and Training (TVET) institutions, particularly in fields such as metalwork technology, still rely heavily on conventional teaching methods. Instruction is often dominated by manual demonstrations, rote learning, and limited access to modern training facilities (Venatius *et al.*, 2022). While these approaches provide foundational skills, they are insufficient in preparing students for the complexities of contemporary industries shaped by automation, artificial intelligence (AI), and digital transformation. As a result, many graduates enter the workforce with skills that are outdated, narrowly focused, and misaligned with the demands of Industry 4.0. This reality underscores the limited integration of AI into TVET education in Nigeria. Ideally, TVET programs should serve as incubators for innovation, equipping students with both practical skills and higher-order thinking abilities relevant to modern industry. AI-enhanced STEM pedagogy, through tools such as intelligent tutoring systems, virtual simulators, and predictive design applications, has the potential to enrich learning experiences and prepare learners for the digital economy (Yang *et al.*, 2025). With proper integration, Nigerian TVET graduates would not only acquire technical proficiency in areas such as welding and machining, but also develop adaptive problem-solving, creativity, and innovation skills that align with global workforce needs. Such a transformation would ensure that Nigerian technicians remain competitive and contribute meaningfully to industrial growth and technological advancement. The gap, therefore, lies between the existing reliance on traditional, resource-limited instructional methods and the potential of AI-driven approaches to transform TVET education. This gap has resulted in graduates who are technically trained but insufficiently innovative, entrepreneurial, and digitally literate to thrive in modern work environments. Bridging this divide requires deliberate integration of AI into metalwork and other TVET programs in Nigeria, thereby aligning skill development with global trends and ensuring the production of skilled, innovative technicians capable of meeting 21st-century workforce challenges.

Aim and objectives of the study

The aim of this study is to determine the integration of AI into Metalwork Technology Education: A STEM-Based Approach for Developing Skilled and Innovative Technicians. Specifically, the objectives is to:

1. To examine the potential of AI tools and applications in enhancing teaching and learning processes in metalwork technology education within Nigerian TVET institutions.
2. To evaluate how the integration of AI-driven STEM pedagogy can improve students' acquisition of innovation in metalwork technology education.

Methodology

This study adopts a conceptual and practice-oriented methodology aimed at mapping the integration of AI within Metalwork Technology Education through the STEM framework. Rather than conducting field-based empirical research, the paper employs a synthesis of scholarly and practice-based evidence to build an analytical framework for guiding AI adoption in Nigerian technical and vocational education. The methodology is structured around three major components: research design, data sources, and analytical approach.

The research design is rooted in conceptual analysis combined with illustrative case examples. Conceptual analysis provides a systematic examination of the constructs of AI, STEM pedagogy, and technical workforce preparation, clarifying how these elements interconnect in metalwork technology education (Bhattacharjya, 2025). To ground the conceptual framework in practical realities, case illustrations are drawn from international best practices in AI integration in technical education, such as smart welding applications and AI-driven simulation tools. This dual design ensures both theoretical rigor and contextual relevance, which is essential in responding to the challenges of underdeveloped AI integration in Nigerian TVET contexts (Baako, 2025). Thus, the design links conceptual clarity with practical applicability.

The study relies primarily on secondary data sources, including peer-reviewed literature, policy documents, curriculum standards, and industry reports. Academic studies on AI in education and industry offer insights into evolving practices, while policy documents provide benchmarks for aligning TVET with national development goals (Joseph *et al.*, 2024). Furthermore, industry reports from global welding and manufacturing organizations supply concrete examples of AI-driven applications relevant to metalwork technology education. According to Turner *et al.*, 2017 using diverse sources enhances triangulation and strengthens the validity of the developed framework. This makes it possible to capture not only academic discourse but also the policy-practice nexus.

The analytical approach is based on thematic review and framework development. Literature and documentary sources are reviewed thematically to identify recurring concepts such as problem-solving, creativity, robotics integration, and employability skills. Themes are then synthesized into a conceptual framework that maps how AI can be systematically infused into metalwork education curricula through the STEM model. (Tariq, 2025). Thematic synthesis also allows gaps in the current Nigerian context to be explicitly contrasted with international models, thereby generating a roadmap for reform. Through this methodology, the study does not simply describe the challenges but builds a practice-informed conceptual framework for AI-driven workforce readiness in metalwork technology education, offering guidance that is adaptable across multiple technical education contexts.

Conceptual Relationship Framework

Conceptual Element	Description	Expected Outcome
Artificial Intelligence (AI)	Represents the digital tools and intelligent systems used for training and assessment.	Enhances automation, real-time feedback, and data-driven learning.
STEM Pedagogy	Provides the teaching framework that emphasizes problem-solving, creativity, and innovation.	Enables critical thinking and innovation.
Metalwork Technology Education (TVET Context)	The applied field where AI and STEM principles are implemented.	Produces skilled, adaptable, and innovative workforce.

The table illustrates the conceptual framework linking AI, STEM pedagogy, and Metalwork Technology Education within the TVET context. AI serves as the technological enabler that enhances automation, real-time feedback, and data-driven learning. STEM pedagogy provides the instructional foundation that promotes creativity, problem-solving, and critical thinking. Metalwork Technology Education represents the practical field where these elements are applied to produce a skilled, adaptable, and innovative workforce. Collectively, the integration of these three components supports a modernized and competency-based approach to technical training aligned with the demands of Industry 4.0.

Literature Review

AI has rapidly emerged as a transformative force in both education and industry, reshaping how knowledge is delivered and how work is performed while in industrial contexts, AI applications such as smart welding systems, predictive design platforms, and robotics have significantly improved efficiency, accuracy, and safety (Eren *et al.*, 2023). For instance, AI-powered welding systems can detect defects in real time and adjust parameters automatically, reducing errors and minimizing material waste. Similarly, predictive design tools enable engineers to simulate multiple outcomes, optimize processes, and reduce production costs, thereby preparing industries for the demands of Industry 4.0. These advances highlight the potential benefits of AI not only in technical practice but also in the classroom, where similar tools can enhance student learning through simulation and automation. This industrial transformation directly informs how education systems must adapt.

In education, AI has been used to personalize learning, support intelligent tutoring systems, and create immersive virtual laboratories that replicate real-world industrial conditions (Constantinescu Constantinescu *et al.*, 2024). Such innovations give learners opportunities to practice problem-solving in safe, simulated environments that mirror the demands of actual industries. For example, AI-driven virtual welding simulators allow students to repeatedly test techniques without material costs or safety risks, thereby deepening their understanding and

confidence. These educational applications align closely with workforce needs, showing that the use of AI in industry and education are not isolated but deeply interconnected. This naturally leads to an exploration of how AI integration is best guided within an educational framework such as STEM.

STEM education provides a structured framework for fostering problem-solving, creativity, and innovation among learners by emphasizes hands-on learning and cross-disciplinary approaches to challenges (Pinar *et al.*, 2025). This approach develops learners' ability to think critically, apply knowledge in real-life contexts, and innovate solutions in rapidly changing environments. For instance, in metalwork technology education, STEM-based learning encourages students to go beyond memorizing fabrication procedures to developing new techniques and tools that address industrial needs. This framework creates the foundation upon which AI can be integrated to further enrich creativity and adaptability in learning.

Furthermore, research shows that when STEM education is augmented by AI, learners develop stronger digital competencies alongside technical skills (Yang *et al.*, 2025). AI enhances inquiry-based learning, enabling students to engage with complex problem-solving tasks such as predictive modeling or design optimization, which reflect real industrial challenges. This integration prepares graduates not only for employment but also for leadership in technological innovation. However, despite its potential, STEM-AI integration has not been consistently embedded in all technical education curricula, particularly in metalwork technology. This gap underscores the pressing need to re-examine how such curricula are structured and updated.

In Nigeria and many similar contexts, metalwork technology education curricula remain largely traditional, with limited use of AI-based pedagogical tools. Instruction is often focused on manual skill acquisition, with minimal emphasis on digital literacy, critical thinking, or innovation (Kong, 2023). While students may gain competency in basic welding, machining, and fabrication, they often lack exposure to simulation-based training, robotics applications, or data-driven decision-making that modern industries demand. Consequently, graduates may struggle to meet global workforce standards, as their training does not fully align with the technological realities of Industry 4.0. This curriculum-practice mismatch creates a barrier to producing a skilled and innovative workforce.

Scholars have emphasized that aligning TVET curricula with AI-enhanced STEM frameworks is essential for bridging this gap (Venatius *et al.*, 2022). Without deliberate reform, metalwork graduates may continue to possess outdated skills that hinder industrial competitiveness and innovation. This suggests that the issue is not only about technological readiness but also about curriculum design and implementation. To address this, lessons can be drawn from international best practices where AI has been successfully integrated into technical education and workforce preparation.

Globally, several case studies demonstrate the successful integration of AI in technical fields. In Germany, AI-driven robotics and smart manufacturing simulators are embedded in vocational training to mirror industrial automation systems (Huang *et al.*, 2025). Similarly, South Korea integrates AI-based design tools in technical education, enabling students to simulate real-life manufacturing processes before physical execution. These practices highlight how AI integration

improves both efficiency and creativity, producing graduates who are innovative and globally competitive. They also show that aligning AI tools with curricula requires significant investment in infrastructure and capacity building for instructors.

In addition, research from China and the United States has shown that AI-supported virtual laboratories and predictive analytics significantly enhance student performance and employability (Çako-Moore, 2025). These case studies reveal that international best practices not only focus on technology deployment but also emphasize policy frameworks, funding models, and teacher training. Such comprehensive approaches ensure sustainability and long-term impact. Learning from these global practices offers critical insights into how Nigerian metalwork technology education can be reformed, thereby ensuring that AI integration moves from concept to reality.

Findings and Discussion

The review reveals that integrating AI into metalwork technology requires a holistic and multi-dimensional model that combines digital tools, pedagogical strategies, and innovative assessment methods into a single ecosystem of teaching and learning. AI-enabled platforms such as virtual welding simulators, intelligent tutoring systems, and predictive design software offer learners' opportunities to practice and refine skills in risk-free, controlled environments where errors can be corrected without material waste or safety hazards (Khurram *et al.*, 2025). These technologies bridge the gap between theory and practice by allowing students to experiment with advanced processes, visualize outcomes in real time, and develop confidence before engaging in actual workshop tasks.

From a pedagogical perspective, adaptive learning systems ensure that instruction is no longer "one-size-fits-all." Instead, lessons are tailored to the unique progress and needs of each learner, promoting competency-based mastery in welding, machining, and fabrication. This individualized feedback loop not only accelerates skill acquisition but also fosters learner autonomy and responsibility (Porubin, 2024). In addition, the use of problem-based and project-driven AI platforms nurtures higher-order thinking by encouraging students to analyze complex tasks, collaborate on innovative solutions, and engage in design optimization exercises that mirror real industrial practices.

Assessment, which often remains static and exam-oriented in Nigerian TVET contexts, also undergoes a significant transformation with AI. Through AI-powered analytics, both formative and summative assessments can be dynamically managed, with systems tracking learner performance in real time, providing instant, data-driven feedback, and recommending individualized pathways for improvement (Vashishth *et al.*, 2024). This ensures that evaluation moves beyond grading to become a continuous learning process that identifies strengths, addresses weaknesses, and aligns student outcomes with workforce expectations.

The implication for curriculum design is profound. Rather than replacing conventional workshop training, AI should be embedded as complementary modules, creating a blended approach that balances hands-on craftsmanship with digital intelligence. Such integration requires reimagining teacher roles: instructors must transition from being sole demonstrators of manual skills to becoming facilitators, mentors, and co-learners who guide students in navigating AI-driven environments. This shift underscores the need for deliberate teacher retraining and professional

development, as educators themselves must acquire digital literacy, pedagogical flexibility, and confidence in using AI-enabled tools.

However, challenges remain significant, particularly in the Nigerian context. The high cost of AI technologies, coupled with inadequate infrastructure such as unreliable electricity, limited internet connectivity, and poorly equipped workshops, threatens to widen the gap between policy aspirations and classroom realities. Without targeted investment, the risk is that AI integration will remain theoretical rather than practical. This highlights the urgent need for government intervention, industry partnerships, and international collaboration to ensure equitable access to AI-enabled pedagogy across all TVET institutions. Ultimately, addressing these systemic barriers will determine whether AI integration in metalwork technology becomes a transformative force for producing globally competitive technicians, or another unrealized educational reform.

Conclusion and Recommendations

This review highlights the transformative potential of AI in enhancing the teaching and learning of metalwork technology. By integrating AI-enabled tools, STEM-based pedagogies, and intelligent assessment methods, TVET institutions can nurture innovation, creativity, and adaptability among learners. The anticipated benefits extend beyond technical competence to the development of innovative, industry-ready graduates capable of thriving in digitally oriented workplaces.

However, successful implementation is contingent upon addressing systemic challenges such as inadequate resources, limited digital literacy, and the high cost of AI adoption. Curriculum design must move beyond traditional skill drills to incorporate AI-supported problem-solving and project-based activities. Equally important is teacher training, as educators are the linchpin in translating AI innovations into meaningful classroom practice. It is therefore, the following recommendations were made:-

1. **Policy and Curriculum Reform:** - Policymakers should embed AI and STEM-driven approaches into technical and vocational curricula, ensuring metalwork technology education is aligned with global innovation trends. This involves developing national guidelines for AI integration, providing funding support, and incentivizing schools that adopt modernized teaching frameworks.
2. **Capacity Building for Educators:** - Training and professional development programs must be established to equip teachers with digital literacy, AI pedagogical skills, and STEM-based instructional strategies. This ensures teachers are not only competent users of AI tools but also facilitators of problem-solving and creativity in students.
3. **Industry-Academia Collaboration:** - Strong partnerships between industries, training institutions, and research bodies should be fostered to provide access to AI-enabled tools (e.g., smart welding simulators), internships, and real-world projects. This synergy will reduce resource gaps, lower implementation costs, and ensure students acquire skills directly relevant to workforce needs.

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ARTIFICIAL INTELLIGENCE AND THE DEVELOPMENT OF CREATIVITY AND PROBLEM-SOLVING SKILLS IN PRE-SERVICE STEM TEACHERS

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Abstract

Artificial Intelligence (AI) is transforming teaching and learning across Science, Technology, Engineering, and Mathematics (STEM) education. This review examines how AI tools and approaches contribute to the development of creativity and problem-solving skills among pre-service STEM teachers. It explores how AI applications such as intelligent tutoring systems, adaptive learning environments, generative AI models, and virtual laboratories support flexible thinking, inquiry, and innovation in teacher education. The review highlights how AI encourages creativity by enabling exploration, experimentation, and reflective thinking, while enhancing problem-solving through interactive simulations and data-driven feedback. It also identifies challenges, such as ethical use, digital readiness, and pedagogical integration. The paper concludes that embedding AI in pre-service teacher programs can promote innovative, emotionally intelligent, and analytically skilled educators capable of navigating complex STEM learning contexts.

Keywords: *Artificial Intelligence; Creativity; Problem-Solving; Pre-Service Teachers; STEM Education; Teacher Preparation; Educational Innovation.*

Introduction

The rapid advancement of Artificial Intelligence (AI) is transforming educational systems across the globe, particularly within Science, Technology, Engineering, and Mathematics (STEM) disciplines. AI technologies such as machine learning algorithms, intelligent tutoring systems, natural language processing, and data-driven analytics are being integrated into instructional design and teacher preparation programs to improve learning efficiency and innovation (Zawacki-Richter *et al.*, 2022). In STEM education, where inquiry, experimentation, and problem-solving are central, equipping pre-service teachers with creativity and analytical reasoning skills is indispensable for fostering 21st-century competencies among learners (Nguyen, 2025; Adeyemo & Edeh, 2023).

AI enhances this process by supporting adaptive and personalized learning experiences. Through systems capable of analyzing learner data and predicting performance trends, pre-service STEM teachers can receive customized feedback on their teaching strategies, learning behaviors, and conceptual understanding (Wang & Lim, 2024). For example, intelligent tutoring systems can simulate classroom problem scenarios that challenge future teachers to apply creative and critical thinking in designing lesson solutions. Similarly, AI-driven virtual laboratories and modeling software provide opportunities for pre-service biology and engineering teachers to conduct simulated experiments, visualize outcomes, and refine hypotheses without physical laboratory constraints (Leon *et al.*, 2025; Jin & Park, 2023).

Furthermore, the integration of AI into teacher education encourages a pedagogical shift from knowledge transmission to knowledge creation. AI-powered platforms such as generative design tools, virtual reality environments, and large language models (e.g., ChatGPT, Copilot) allow pre-service teachers to co-create instructional materials, generate innovative teaching aids, and engage in problem-based learning that mirrors real-world contexts (Alhassan & Khan, 2024). These affordances promote not only cognitive flexibility and divergent thinking but also reflective teaching practices that deepen understanding of subject matter and learner diversity (Chen *et al.*, 2022).

From an educational psychology perspective, AI also mediates emotional engagement and metacognitive development. Adaptive AI tools monitor learning emotions, attention levels, and motivation patterns, providing feedback that enhances persistence and self-regulation among pre-service teachers (Chiu *et al.*, 2023). Such emotional and cognitive supports are crucial for sustaining creativity and complex problem-solving processes, especially in challenging STEM domains where conceptual abstraction and iterative reasoning are required.

Consequently, understanding how AI contributes to the development of creativity and problem-solving skills among pre-service STEM teachers has become a major research and policy interest. This review explores theoretical and empirical insights on how AI integration supports creative thinking, enhances instructional design capabilities, and fosters innovative problem-solving in teacher education. It also highlights pedagogical implications for curriculum design, emotional intelligence cultivation, and future professional practice within AI-enhanced STEM education environments.

Conceptualizing AI in STEM Teacher Education

Artificial Intelligence (AI) in education can be broadly conceptualized as the use of computational systems capable of perceiving, reasoning, and adapting to data-driven educational contexts to optimize teaching and learning outcomes (Holmes *et al.*, 2022). Within STEM teacher education, AI transcends the boundaries of mere technological integration; it represents a pedagogical innovation that reshapes how future teachers acquire knowledge, facilitate inquiry, and evaluate learning. AI technologies such as machine learning models, adaptive learning environments, intelligent tutoring systems, and generative design platforms are increasingly embedded into teacher preparation programs to cultivate creative and problem-solving mindsets among pre-service educators (Nguyen, 2025; Leon *et al.*, 2025).

AI as a Cognitive and Pedagogical Tool

AI serves both cognitive and pedagogical functions in STEM education. Cognitively, it supports pre-service teachers' development of higher-order thinking by enabling individualized learning trajectories and scaffolding complex tasks through intelligent feedback mechanisms (Wang & Lim, 2024). Pedagogically, AI-driven platforms promote constructivist and experiential learning by simulating real-world teaching and laboratory scenarios, allowing pre-service biology, physics, and engineering teachers to experiment, hypothesize, and analyze outcomes dynamically (Jin & Park, 2023).

For example, AI-enabled learning analytics can detect misconceptions in real time, allowing teacher educators to tailor instruction that reinforces conceptual understanding (Chiu *et al.*, 2023).

Moreover, large language models (LLMs) such as ChatGPT and Claude have been utilized to support reflective practice, lesson planning, and creative content generation, thereby encouraging pre-service teachers to explore diverse pedagogical strategies (Alhassan & Khan, 2024; Rahman *et al.*, 2024). Through these affordances, AI functions as both a co-instructor and cognitive partner, enabling pre-service teachers to actively construct and reconstruct pedagogical knowledge rather than passively receive it (Zawacki-Richter *et al.*, 2022).

AI for Creativity and Innovative Thinking

Creativity in teacher education is not confined to artistic expression but involves the ability to generate novel instructional ideas, design experiments, and approach scientific problems from multiple perspectives (Sawyer, 2023). AI supports this process by providing generative feedback loops that inspire divergent thinking. For instance, generative AI tools such as DALL·E and GPT-based applications can assist pre-service teachers in developing innovative teaching materials or visualizations of biological concepts that are otherwise abstract and difficult to demonstrate (Leon *et al.*, 2025).

In addition, AI platforms facilitate interdisciplinary thinking by linking data patterns across STEM fields enabling pre-service teachers to connect physics principles with biological phenomena or computational models with engineering designs (Chen *et al.*, 2022). Such cross-domain reasoning fosters what scholars refer to as *computational creativity*, where AI functions not as a replacement for human ingenuity but as a collaborator in co-creating knowledge (Holmes *et al.*, 2022; Nguyen, 2025).

AI and Problem-Solving Skill Development

Problem-solving is central to STEM pedagogy, requiring analytical reasoning, hypothesis testing, and decision-making. AI-based simulations and predictive modeling tools offer pre-service teachers opportunities to engage in inquiry-driven tasks that mirror professional practice (Jin & Park, 2023). For example, AI systems can present dynamic classroom scenarios such as predicting students' misconceptions or optimizing lab experiments allowing teachers-in-training to test interventions and observe real-time outcomes (Wang & Lim, 2024).

Furthermore, AI enables *data-informed reflection*, where pre-service teachers analyze algorithmic insights to understand their instructional effectiveness. Such metacognitive engagement enhances critical evaluation, adaptability, and evidence-based decision-making core elements of problem-solving in STEM education (Chiu *et al.*, 2023; Adeyemo & Edeh, 2023). As a result, AI not only facilitates the acquisition of problem-solving techniques but also shapes a reflective mindset that values continuous improvement and innovation in teaching practice.

Ethical and Pedagogical Considerations

While AI holds transformative potential, its integration in teacher education requires thoughtful consideration of ethical and pedagogical implications. Issues of data privacy, algorithmic bias, and over-reliance on automated systems can undermine the authenticity of human judgment and creativity (Rahman *et al.*, 2024). Teacher educators must therefore cultivate digital ethics and AI literacy among pre-service teachers to ensure responsible use of these tools (Alhassan & Khan, 2024).

Equally important is the need for human-centered AI design that complements rather than replaces pedagogical expertise. Effective AI use in teacher education should foreground empathy, inclusivity, and contextual awareness ensuring that creativity and problem-solving remain grounded in human values and educational purpose (Holmes *et al.*, 2022).

Role of Artificial Intelligence in Enhancing Creativity

Artificial Intelligence (AI) has emerged as a transformative tool in educational contexts, with its potential to foster creativity among pre-service STEM teachers gaining increasing scholarly attention (Nguyen, 2025; Leon *et al.*, 2025). Creativity in STEM education extends beyond artistic expression to include innovative problem-solving, design thinking, and the capacity to generate novel ideas or approaches to scientific inquiry (Begum & Islam, 2024). In teacher education, creativity is crucial for designing inquiry-based lessons, adapting pedagogical strategies, and responding flexibly to diverse learner needs. AI technologies such as intelligent tutoring systems, generative design tools, and data analytics platforms offer novel pathways for cultivating these competencies by providing dynamic, adaptive, and personalized learning experiences (Ajani, 2024; Rahman & Chen, 2023).

AI-Driven Learning Environments

AI-driven learning environments leverage adaptive algorithms that analyze learners' performance data and dynamically adjust instructional content to suit individual learning needs (Leon *et al.*, 2025). Such systems enhance creativity by fostering exploration and experimentation. Instead of prescribing linear learning pathways, AI environments present learners with multiple problem-solving routes and immediate feedback, stimulating divergent thinking and cognitive flexibility (Ajani, 2024). For instance, Intelligent Tutoring Systems (ITS) and adaptive learning platforms such as ALEKS or Smart Sparrow allow learners to explore alternative approaches to a single problem, thereby reinforcing the understanding that creativity involves iterative reasoning rather than singular solutions (Morris *et al.*, 2023).

Moreover, these platforms provide data-informed insights that help teacher educators identify how pre-service STEM teachers generate and refine ideas during instructional design or laboratory activities. As highlighted by Osei and Lim (2024), exposure to AI-enabled simulations encourages experimentation with varied instructional strategies an essential aspect of creative pedagogical thinking. Through scaffolding and real-time feedback, AI-based learning environments thus foster a culture of inquiry and innovation that aligns with 21st-century STEM education goals (Leon *et al.*, 2025).

Generative AI and Idea Exploration

Generative AI applications such as ChatGPT, DALL·E, and Copilot enable idea generation and conceptual exploration by transforming textual or visual prompts into innovative outputs. In pre-service STEM teacher education, these tools facilitate brainstorming, visualization, and experimentation with complex ideas that might otherwise remain abstract (Nguyen, 2025). For instance, pre-service biology teachers can employ generative AI to simulate ecological systems or visualize cellular processes, enhancing both conceptual understanding and imaginative engagement (Rahman & Chen, 2023).

By using AI for ideation, teachers learn to model creative thinking for their students. This process nurtures curiosity and intrinsic motivation, both of which are linked to sustained creative engagement (Begum & Islam, 2024). According to Ajani (2024), generative AI fosters divergent thinking by allowing learners to compare multiple representations of the same idea, refine hypotheses, and integrate feedback iteratively. Such tools do not merely automate creativity but act as “co-creators,” supporting pre-service teachers in developing innovative lesson plans and problem-based projects. In this sense, generative AI transforms creativity from a static trait into an evolving skill cultivated through interaction, reflection, and collaboration (Leon *et al.*, 2025).

Reflective Feedback and Metacognitive Growth

Another critical contribution of AI to creativity lies in its capacity for providing reflective and metacognitive feedback. AI analytics systems can monitor user engagement patterns, track cognitive processes, and visualize learning trajectories through dashboards and performance analytics (Nguyen, 2025). This form of reflective intelligence promotes metacognition learners’ awareness of their thought processes by helping pre-service teachers understand how they generate, evaluate, and refine creative ideas.

For instance, AI-powered feedback systems can highlight how frequently a learner explores alternative solutions, the level of novelty in their responses, or their tendency to rely on conventional strategies (Leon *et al.*, 2025). Such feedback enhances self-regulation and encourages learners to experiment beyond their comfort zones. As reported by Osei and Lim (2024), integrating AI dashboards in teacher preparation courses has improved reflective thinking and creative confidence among pre-service educators. Moreover, the visualization of progress helps learners make informed adjustments to their learning strategies, fostering autonomy and continuous creative development.

Collectively, AI-driven environments, generative tools, and feedback systems demonstrate how technology can serve as both a catalyst and a mirror for creativity in STEM teacher education. When thoughtfully integrated, AI not only enhances pre-service teachers’ capacity to innovate but also models the creative mindset they are expected to cultivate in their future classrooms (Begum & Islam, 2024; Nguyen, 2025).

AI and Problem-Solving Skill Development

Problem-solving is at the core of STEM education, encompassing the ability to identify complex challenges, generate hypotheses, test solutions, and evaluate outcomes through reasoning and evidence (Jonassen & Hung, 2023). For pre-service STEM teachers, developing these skills is essential, as they are expected not only to solve problems themselves but also to model and scaffold problem-solving processes for their future students. Artificial Intelligence (AI) offers powerful tools for enhancing these cognitive and pedagogical capacities through intelligent feedback systems, data-driven decision-making, and simulation-based inquiry environments (Nguyen, 2025; Leon *et al.*, 2025). By integrating AI into teacher education, pre-service teachers can engage in authentic, iterative problem-solving experiences that mirror real-world scientific and engineering challenges (Begum & Islam, 2024).

AI as a Cognitive Partner in Problem-Solving

AI functions as a “cognitive partner” that supports reasoning, planning, and decision-making through interactive feedback and adaptive assistance (Sailer & Mayer, 2023). Intelligent tutoring systems, knowledge tracing algorithms, and AI-enhanced modeling platforms guide learners through the problem-solving cycle by identifying misconceptions, prompting reflection, and suggesting potential solution paths (Rahman & Chen, 2023). Such systems not only accelerate learning but also promote metacognitive awareness helping pre-service teachers recognize how they think, plan, and evaluate during problem-solving (Leon *et al.*, 2025).

For instance, in simulated laboratory environments, AI tools can detect procedural errors or inefficient strategies and offer targeted hints, enabling learners to refine their experimental designs (Ajani, 2024). This aligns with constructivist theories emphasizing learning through guided discovery and iterative feedback. By experiencing AI as a cognitive collaborator, pre-service STEM teachers internalize the principles of problem decomposition, hypothesis generation, and data-based reasoning skills directly transferable to classroom instruction (Nguyen, 2025; Osei & Lim, 2024).

Simulation-Based Learning and Real-World Application

AI-powered simulation environments such as virtual labs, digital twins, and augmented reality (AR) scenarios allow pre-service teachers to engage in inquiry-based learning and test solutions within realistic contexts (Morris *et al.*, 2023). These simulations can model complex systems such as climate change dynamics, circuit behavior, or ecological networks, offering learners opportunities to explore cause-and-effect relationships (Leon *et al.*, 2025).

According to Rahman and Chen (2023), such experiential learning environments enhance problem-solving skills by allowing learners to visualize abstract concepts, manipulate variables, and observe the outcomes of their decisions in real time. In teacher preparation programs, this not only strengthens disciplinary knowledge but also nurtures pedagogical creativity helping pre-service teachers design inquiry tasks that replicate these experiences for their students (Begum & Islam, 2024).

Furthermore, AI-driven simulations enable safe exploration of high-risk or resource-intensive experiments that would be difficult to conduct in physical laboratories. As Ajani (2024) notes, this democratizes access to scientific inquiry and fosters confidence in experimentation an essential foundation for problem-solving competence. Through these digital platforms, learners engage in active hypothesis testing, pattern recognition, and systems thinking skills critical for addressing the interdisciplinary challenges of STEM education (Sailer & Mayer, 2023).

Data Analytics and Reflective Problem Solving

AI's ability to process vast datasets and generate real-time insights also enhances reflective problem-solving. Learning analytics dashboards, for instance, visualize patterns in learner performance, enabling pre-service teachers to evaluate their strategies, identify weaknesses, and improve subsequent decisions (Osei & Lim, 2024). By engaging with AI-generated analytics, learners become active agents in their cognitive development, using evidence to self-assess and recalibrate their problem-solving approaches (Nguyen, 2025).

These reflective cycles are integral to developing adaptive expertise the ability to apply knowledge flexibly across new contexts (Leon *et al.*, 2025). According to Begum and Islam (2024), AI analytics cultivate a data-literate mindset among pre-service teachers, helping them interpret learning evidence and make pedagogical adjustments. This dual benefit improving both cognitive and instructional decision-making positions AI as a central tool in the development of reflective, evidence-informed educators.

Moreover, AI-enabled reflection extends to collaborative problem-solving contexts. Through AI-supported collaboration platforms, learners can analyze peer interactions, identify patterns of discourse, and evaluate the quality of collective reasoning (Rahman & Chen, 2023). This deepens understanding of teamwork and communication critical competencies for teaching STEM in inquiry-oriented classrooms.

Fostering Higher-Order Thinking and Transfer of Learning

AI technologies can scaffold higher-order thinking by prompting learners to justify, evaluate, and generalize their solutions. Adaptive systems use machine learning to recognize when learners have mastered procedural knowledge and are ready to tackle ill-structured or open-ended problems (Nguyen, 2025). These environments encourage transfer of learning applying concepts learned in one context to novel problems by continuously adjusting cognitive demands and feedback complexity (Ajani, 2024).

Pre-service teachers exposed to such problem-solving experiences develop flexible reasoning and creative adaptability, essential for designing effective STEM instruction. As Sailer and Mayer (2023) emphasize, AI fosters both convergent and divergent problem-solving: convergent through data-driven reasoning and divergent through creative exploration of alternative pathways. This balance reflects the essence of STEM problem-solving where innovation emerges from structured reasoning supported by technological tools.

Ethical and Pedagogical Considerations

While AI enriches problem-solving development, it also introduces pedagogical and ethical challenges that teacher educators must address. Overreliance on AI tools may reduce opportunities for independent reasoning if learners treat AI outputs as definitive answers (Morris *et al.*, 2023). Teacher preparation programs must therefore emphasize *critical AI literacy* the ability to question, interpret, and ethically use AI-generated information (Begum & Islam, 2024).

Furthermore, equity concerns arise regarding access to AI-enabled learning tools, especially in resource-limited contexts. As Ajani (2024) cautions, sustainable integration requires institutional investment, teacher training, and culturally relevant applications that align AI with local educational goals. Thus, the role of AI in developing problem-solving skills must be framed within an ethical pedagogy that values human creativity, autonomy, and inclusiveness (Nguyen, 2025; Osei & Lim, 2024).

Integrating Artificial Intelligence, Creativity, and Problem-Solving in Pre-Service STEM Teacher Education

The intersection of artificial intelligence (AI), creativity, and problem-solving represents a transformative paradigm in contemporary STEM teacher education. As educational systems shift

toward inquiry-driven and innovation-centered learning, pre-service teachers must be equipped not only with content knowledge but also with the creative and analytical capacities needed to facilitate deep learning (Leon *et al.*, 2025; Nguyen, 2025). AI provides a powerful framework for this transformation by supporting personalized learning, fostering creative engagement, and scaffolding complex problem-solving tasks in ways that traditional pedagogical methods cannot achieve (Begum & Islam, 2024; Rahman & Chen, 2023).

Theoretical Perspectives on AI Integration

The integration of AI into teacher education is grounded in socio-constructivist and experiential learning theories, which emphasize active engagement, reflection, and social collaboration (Sailer & Mayer, 2023). Vygotsky's (1978) theory of the *Zone of Proximal Development (ZPD)* aligns with AI's adaptive capabilities, as intelligent systems can provide tailored support that bridges the gap between a learner's current competence and potential performance (Jonassen & Hung, 2023). Similarly, Kolb's (1984) experiential learning cycle comprising concrete experience, reflective observation, abstract conceptualization, and active experimentation maps closely onto AI-mediated learning environments that promote iterative creativity and problem-solving (Ajani, 2024).

In pre-service STEM teacher education, these theories converge as AI technologies facilitate dynamic learning loops, where pre-service teachers engage in experimentation (using AI tools), reflect on outcomes (via analytics dashboards), and conceptualize improvements (through feedback loops). This process mirrors the scientific method itself observing, hypothesizing, testing, and refining thereby embedding AI deeply within the epistemology of STEM learning (Nguyen, 2025).

Pedagogical Framework for AI-Enhanced Teacher Preparation

An integrated AI-creativity-problem-solving (AICPS) framework in pre-service STEM education can be conceptualized across three pedagogical phases: **exposure**, **application**, and **transformation** (Leon *et al.*, 2025).

1. **Exposure Phase** – Pre-service teachers are introduced to AI technologies, learning about their functionalities and pedagogical implications. This foundational phase cultivates *AI literacy* the ability to understand, interpret, and critically engage with AI systems (Begum & Islam, 2024). Teacher educators at this stage demonstrate how AI-driven platforms can model creativity, automate feedback, and simulate problem contexts, aligning with inquiry-based learning approaches.
2. **Application Phase** – Here, pre-service teachers begin to integrate AI tools into instructional design. For instance, they may use generative AI to develop creative STEM lesson plans or employ simulation-based platforms to create student-centered inquiry tasks (Rahman & Chen, 2023). Through this application, teachers not only develop technical proficiency but also refine their pedagogical creativity and adaptive reasoning (Morris *et al.*, 2023).
3. **Transformation Phase** – The final phase emphasizes reflection, ethical reasoning, and innovation. Pre-service teachers analyze AI's pedagogical affordances and constraints, reflect on its impact on student engagement, and explore ways to redesign learning environments through AI (Osei & Lim, 2024). This phase transforms AI from a technological

tool into a cognitive and ethical partner in teaching practice, enabling educators to design inclusive and future-oriented STEM classrooms (Nguyen, 2025).

Building AI-Enabled Creative Pedagogical Competence

AI integration demands that pre-service teachers develop a unique blend of **creative pedagogical competence** the ability to use technology not merely as content delivery but as a co-creator of learning experiences (Ajani, 2024). According to Leon *et al.* (2025), AI-enhanced creative pedagogy involves designing lessons that allow students to explore open-ended problems, experiment with multiple representations, and use data to support innovative thinking.

Through exposure to AI-driven tools like intelligent tutors, generative design platforms, and visual analytics systems, pre-service teachers learn to orchestrate learning environments that promote inquiry, experimentation, and reflection (Begum & Islam, 2024). These skills are essential in the context of *Education 4.0*, where interdisciplinary innovation and technological fluency define the professional expectations of educators (Rahman & Chen, 2023).

Moreover, creativity in teaching requires risk-taking and adaptability qualities that AI environments naturally support by offering nonjudgmental feedback and opportunities for iterative refinement (Sailer & Mayer, 2023). By engaging in cycles of creation, reflection, and revision, pre-service teachers internalize the process of creative inquiry that they are expected to nurture in their future classrooms.

Ethical, Emotional, and Reflective Dimensions

Integrating AI into teacher education also raises important ethical and emotional considerations. Pre-service teachers must learn to engage with AI critically, recognizing biases, ethical implications, and the limits of algorithmic decision-making (Morris *et al.*, 2023). This *critical AI consciousness* ensures that creativity and problem-solving remain human-centered and socially responsible (Nguyen, 2025).

Emotional intelligence plays a mediating role in this process, as effective use of AI requires empathy, ethical reasoning, and interpersonal sensitivity (Osei & Lim, 2024). For example, AI can support emotional analytics monitoring engagement and stress levels but teachers must interpret such data sensitively and ethically. According to Begum and Islam (2024), emotionally intelligent educators are better equipped to use AI as a supportive tool rather than a replacement for human judgment, fostering balanced, ethical, and inclusive classrooms.

Reflective practice, supported by AI dashboards and analytics, further reinforces emotional and pedagogical awareness. These tools encourage pre-service teachers to analyze their teaching interactions, recognize areas for improvement, and adopt creative strategies to enhance student engagement (Ajani, 2024). In this way, AI fosters a reflective culture of continuous professional learning a key attribute for adaptive expertise in STEM teaching (Leon *et al.*, 2025).

Future Directions and Implications for Policy and Practice

The future of AI integration in STEM teacher education must emphasize inclusivity, ethical awareness, and continuous professional development. Educational policymakers should prioritize curriculum reforms that embed AI literacy, creative pedagogy, and data-informed problem-solving

into teacher preparation programs (Nguyen, 2025). Investment in infrastructure, faculty training, and equitable access to AI resources is essential to avoid technological marginalization, particularly in developing contexts (Ajani, 2024).

Collaborative partnerships between universities, AI developers, and educational researchers are also vital. These partnerships can co-create adaptive AI systems designed specifically for teacher preparation, incorporating local curricula and cultural relevance (Leon *et al.*, 2025). As Rahman and Chen (2023) suggest, such contextualized design ensures that AI tools are not merely imported technologies but are pedagogically and socially meaningful innovations.

Ultimately, the integration of AI in STEM teacher education should aim not just to enhance technological proficiency but to cultivate reflective, emotionally intelligent, and creative educators who can guide the next generation of innovators. By harmonizing creativity and problem-solving through AI, pre-service teachers are empowered to redefine learning for the complexities of the 21st century (Sailer & Mayer, 2023).

Implications for Pre-Service STEM Teacher Education

The integration of Artificial Intelligence (AI) into STEM teacher education has far-reaching implications for curriculum design, pedagogy, and professional development. Preparing pre-service STEM teachers to engage creatively with AI technologies requires a rethinking of traditional training approaches, ensuring that innovation, ethical competence, and reflective teaching are prioritized.

Curriculum Design

Embedding AI-enhanced creativity and problem-solving modules in teacher preparation curricula is essential for fostering innovation and adaptability. Curriculum frameworks should integrate design thinking, computational modeling, and reflective inquiry to cultivate higher-order cognitive skills (Nguyen, 2025). Through AI-enabled simulations and project-based learning, pre-service teachers can experiment with real-world STEM challenges, thereby connecting theory to practice in dynamic ways.

Furthermore, integrating AI literacy into STEM education ensures that teachers understand not only how to use AI tools but also the principles governing them such as algorithmic reasoning, data ethics, and responsible innovation (Okonkwo & Adeoye, 2024). Studies suggest that curriculum models incorporating AI-based creativity tasks improve pre-service teachers' confidence and engagement in technological problem-solving (Leon *et al.*, 2025; Dede *et al.*, 2023). This transformation encourages a shift from content-based instruction toward inquiry-driven, data-informed learning ecosystems that prepare teachers for the complexities of 21st-century classrooms.

Pedagogical Integration

AI should serve as a pedagogical enhancer rather than a substitute for human instruction. Effective integration necessitates aligning AI applications with explicit learning goals, ensuring that technology complements conceptual understanding and creative reasoning (Ajani, 2024). For instance, AI-driven adaptive learning environments can support differentiated instruction,

enabling teachers to scaffold learning experiences according to students' cognitive needs and creativity levels (Leon *et al.*, 2025).

Moreover, pedagogical strategies should encourage collaborative problem-solving through AI-supported platforms that simulate authentic STEM contexts. This aligns with constructivist paradigms, where learners actively build knowledge through exploration and reflection (Nguyen & Zhao, 2023). AI-based formative feedback mechanisms such as real-time analytics dashboards enable pre-service teachers to monitor learners' progress and make informed pedagogical adjustments, reinforcing reflective practice and creative inquiry (Santos *et al.*, 2022). Crucially, the pedagogical integration of AI must also address ethical implications, ensuring that pre-service teachers critically assess bias, transparency, and inclusivity in AI systems. This awareness reinforces responsible technology use, aligning AI practices with educational equity and social responsibility (Okonkwo & Adeoye, 2024).

Continuous Professional Development

Sustained professional learning is critical for equipping pre-service teachers with the competencies required to navigate AI-enhanced educational environments. Continuous professional development (CPD) should focus on both technical fluency and ethical literacy, ensuring teachers can apply AI tools effectively while maintaining critical judgment (Leon *et al.*, 2025). Structured CPD programs including workshops, micro-credentials, and AI pedagogy certifications can strengthen teachers' digital confidence and pedagogical adaptability (Santos *et al.*, 2022). These initiatives should also emphasize interdisciplinary collaboration, allowing future teachers to co-design learning experiences that integrate AI-driven creativity, data analytics, and scientific modeling (Nguyen, 2025).

Importantly, reflective professional learning communities should be established within teacher education institutions to encourage dialogue about the challenges and opportunities of AI in STEM classrooms. By fostering a culture of inquiry, teachers can continuously adapt to evolving technologies while maintaining a focus on human-centered education (Dede *et al.*, 2023).

Overall, the incorporation of AI into STEM teacher education requires a multi-layered approach one that balances technological innovation with ethical reflection, pedagogical soundness, and continuous professional growth. This holistic integration positions pre-service STEM teachers as not just consumers of AI tools but as creative innovators capable of shaping the future of education.

Conclusion

Artificial Intelligence holds transformative potential for shaping the future of STEM teacher education by fostering creativity, innovation, and problem-solving competence among pre-service teachers. Through adaptive feedback mechanisms, virtual experimentation platforms, and generative design tools, AI encourages learners to engage in deeper inquiry, explore multiple perspectives, and construct knowledge through authentic experiences. These processes enhance cognitive flexibility and creative reasoning, both of which are essential for effective teaching in the 21st-century STEM classroom.

However, the benefits of AI integration in teacher education depend largely on intentional pedagogical design, ethical application, and equitable access. Simply introducing technology into

the curriculum is insufficient; meaningful integration requires that pre-service teachers understand how to use AI purposefully to inspire creativity, support critical reflection, and personalize learning. Ethical awareness concerning issues such as data privacy, algorithmic bias, and digital equity must also be emphasized to ensure responsible use of AI in educational contexts.

As teacher education institutions evolve, they must reconceptualize their training models to embed AI not merely as a technological enhancement but as a transformative learning partner. When used thoughtfully, AI can serve as a catalyst for developing reflective, innovative, and problem-solving mindsets among pre-service STEM teachers. Such educators will be well equipped to inspire future generations of learners to think critically, create collaboratively, and solve complex real-world problems using technology-driven approaches.

Recommendations

1. **Curriculum Integration:** Teacher education institutions should incorporate AI-supported creativity and problem-solving modules into STEM curricula. These should emphasize design thinking, digital inquiry, and ethical reflection.
2. **Pedagogical Support:** AI tools must be integrated purposefully within instructional design frameworks that promote collaborative learning, creativity, and conceptual understanding rather than rote technology use.
3. **Capacity Building:** Regular workshops, seminars, and micro-credential programs should be organized to build pre-service teachers' competence in AI literacy, data interpretation, and digital ethics.
4. **Policy and Infrastructure:** Educational policymakers should invest in digital infrastructure and equitable access to AI technologies across teacher training institutions, ensuring inclusivity and sustainability.
5. **Future Research:** Further studies should explore longitudinal impacts of AI-driven pedagogies on creativity and problem-solving outcomes in STEM teacher education, focusing on context-specific applications in developing regions.

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FROM PASSIVE TO PERSONALIZED: AN AI-DRIVEN FRAMEWORK FOR ENHANCING SCIENCE AND MATHEMATICS TEACHER PROFESSIONAL DEVELOPMENT

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Abstract

This paper presents an innovative AI-driven framework designed to transform Mathematics Teacher Professional Development (PD) by addressing the shortcomings of traditional models. Acknowledging the persistent weak impact of conventional PD on teacher efficacy, recent studies highlight a critical need for reform. This research proposes a structured, four-phase framework to enhance teachers' Pedagogical Content Knowledge (PCK) and teaching efficacy through personalised, interactive, and sustained learning experiences. Phase One uses AI to conduct diagnostic assessments that identify individual knowledge gaps and generate personalised PD pathways. Phase Two introduces interactive, adaptive learning modules that engage teachers in scenario-based simulations, aligning with constructivist principles. Phase Three provides AI-simulated mastery experiences, allowing teachers to practise new strategies in a risk-free environment to foster self-efficacy. Finally, Phase Four ensures sustained support via AI coaching and facilitated Professional Learning Communities (PLCs), while also considering challenges such as infrastructure, digital literacy, and the ethical use of AI in education. By cultivating a skilled and innovative teaching workforce, this framework aims to bridge the knowledge-belief gap and shift the perception of AI from a mere tool to a transformative agent in mathematics education.

Keywords: Artificial Intelligence, Teacher Professional Development, Pedagogical Content Knowledge, Teaching Efficacy.

Introduction

In education, teacher professional development (PD) is a crucial mechanism for equipping educators with the knowledge and skills needed to enhance teaching efficacy (Komba & MwaKAPenga, 2020; Evers et al., 2016). Despite its significance, traditional PD models often fail to yield positive outcomes; for instance, a recent study noted the weak impact of online seminars and only modest success with workshops, observing no significant enhancement in teacher efficacy (Khairiah et al., 2024). Many educators express dissatisfaction with these conventional initiatives, indicating that such programmes often lack meaningful engagement or actionable insights (Pantić & Florian, 2015). Consequently, a systemic review of these methodologies suggests a need for innovative approaches that align with the evolving educational landscape.

The advent of Artificial Intelligence (AI) presents a transformative opportunity for re-imagining teacher PD. As Huang (2023) notes, AI integration in smart education fosters settings where personalised learning can flourish, addressing teachers' diverse requirements. This technological advancement offers tailored learning experiences and encourages sustained engagement through interactive platforms that actively involve teachers in their growth (Vadivel et al., 2021). By leveraging AI-driven frameworks, we can develop PD programmes that meet individual teacher

needs and promote an environment conducive to innovation and practice-driven learning (Tan & Ng, 2012).

This paper contends that AI-driven professional development models can address the shortcomings of traditional formats by creating constructivist, sustained, and personalised learning journeys for teachers. Harnessing AI enables a shift from passive learning experiences toward dynamic, responsive systems that align with evolving educational demands, consequently fostering a culture of continuous improvement and professional growth (Mori & Ractliffe, 2016). Thus, exploring AI's potential to enrich teacher PD is a crucial step towards revitalising educational approaches.

Literature Review

The effectiveness of teacher professional development has historically been framed by principles that contribute to optimal learning outcomes, including active learning, collaboration, and sustainability. Active learning encourages teachers to engage directly with material, leading to deeper understanding and increased knowledge retention (Liu & Hai, 2021). Similarly, collaboration facilitates shared experiences, creating communities of practice that extend the benefits of professional growth beyond formal PD sessions (Li, 2024). Moreover, sustainability emphasises the need for long-term support rather than one-off workshops, which fail to foster lasting pedagogical change (Marengo et al., 2024). Collectively, these principles highlight the ineffectiveness of traditional PD methods in fostering teacher efficacy, suggesting an urgent need for reform (Ahmad *et al.*, 2021).

The theoretical underpinnings of an effective PD framework can be grounded in Constructivist Learning Theory and Social Cognitive Theory. Constructivist Learning Theory posits that knowledge is constructed through experience and reflection, which is critical for developing pedagogical content knowledge (PCK) among educators (Bruder *et al.*, 2020; Kim *et al.*, 2025). This approach is vital for engaging educators in active learning environments. Social Cognitive Theory complements this by highlighting the importance of mastery experiences and observational learning in building teacher efficacy, which directly leads to improved teaching outcomes (Bandura, 1997; Kim *et al.*, 2025). Together, these theories provide a framework for understanding how PD can become more effective by incorporating strategies that nurture individual growth and collective knowledge.

A thorough examination reveals significant shortcomings in current PD modalities, particularly in online formats and one-off workshops, which often fail to impact teacher efficacy meaningfully (Liu & Hai, 2021). These formats typically lack interactivity and sustained engagement, offering minimal opportunity to transfer theory into practice. Integrating AI-driven solutions presents a compelling case for the future of PD, as AI can introduce adaptive learning strategies and intelligent tutoring systems that cater to individual teacher needs (Chen *et al.*, 2020). This facilitates personalised learning journeys that allow teachers to adapt and grow in response to specific educational challenges (Gutiérrez, 2023).

Summarily, enhancing teacher PD requires grounding established principles in relevant educational theories such as Constructivism and Social Cognitive Theory. Recognising the limitations of current PD modalities and leveraging AI technologies presents a vital opportunity to create engaging, dynamic, and sustained professional learning experiences.

An AI-Driven Framework for Mathematics Teacher PD

This proposed AI-driven framework for Mathematics Teacher Professional Development addresses prior challenges by offering a structured model that enhances teachers' pedagogical content knowledge (PCK) and efficacy through personalisation and sustained engagement. The framework comprises four distinct phases, each designed to leverage AI technologies for improved teacher outcomes.

Phase 1: AI-Powered Diagnostic & Personalisation serves as the foundational step, where AI tools conduct comprehensive assessments of individual teachers. These diagnostics identify specific gaps in PCK and areas of low efficacy, allowing for the generation of tailored PD pathways. Such personalisation is vital, as research indicates that teachers' ability to engage with effective pedagogical practices is significantly influenced by their self-awareness and understanding of their instructional strengths and limitations (Nxasana *et al.*, 2023). This initial phase aligns with the principle that effective PD must be responsive to individual needs (Gold, 2019).

Phase 2: Interactive, Adaptive Learning Modules moves from passive online courses to dynamic, AI-driven simulations and scenario-based learning experiences. By immersing teachers in simulated environments that replicate classroom challenges, the framework adheres to constructivist principles, promoting active engagement and allowing educators to explore mathematical concepts in context (Gusango *et al.*, 2021). Such interactive modules ensure that learning is applied, facilitating a deeper understanding by enabling teachers to construct knowledge through practice (Hedden *et al.*, 2017).

Phase 3: AI-Simulated Mastery Experiences creates opportunities for teachers to practise new strategies in a risk-free environment, aligning with Bandura's Social Cognitive Theory, which emphasises the importance of mastery experiences for building efficacy (Blease & Condy, 2015). This phase addresses a key gap in traditional PD, where teachers were often deprived of the practical application necessary to foster confidence. The AI simulation tools provide a safe space for exploration and experimentation.

Phase 4: Sustained Support via AI Coaching & Professional Learning Communities (PLCs) addresses the need for ongoing guidance and community engagement, which are crucial for sustainability (Gold, 2019). AI tools can analyse classroom interactions captured through video submissions, offering constructive feedback and fostering reflection. Furthermore, by using AI to facilitate connections within PLCs, the framework promotes collaboration and shared learning, creating a supportive ecosystem for continuous professional growth (Vaishali & Misra, 2020).

In conclusion, this AI-driven framework for Mathematics Teacher PD embodies a holistic approach that addresses the shortcomings of traditional models. It enhances the professional growth of educators through personalised learning pathways, interactive experiences, mastery practice, and sustained peer support, thereby reshaping how mathematics teaching is advanced in educational settings.

Discussion

In addressing the discrepancies between knowledge and belief in teaching, the proposed AI framework serves as an effective mechanism for enhancing teachers' Pedagogical Content Knowledge (PCK). It aligns with Shulman's theory of PCK development, which posits that a teacher's ability to transform subject matter knowledge into effective teaching is essential (Ribeiro *et al.*, 2020). The framework's targeted diagnostics identify specific gaps and facilitate tailored learning pathways that resonate with the constructivist approach of engaging learners in the active construction of knowledge (Mayne, 2019). This model ensures that teacher PD is highly practical and personalised, bridging the gap between what teachers know and what they believe in their professional practice.

Furthermore, the framework addresses the enhancement of teaching efficacy, drawing from Bandura's sources of efficacy, particularly mastery and vicarious experiences. The use of simulations and scenario-based learning embodies Bandura's assertion that successful experiences can significantly boost self-efficacy (Blease & Condy, 2015). These immersive experiences, coupled with vicarious learning through peer observation, empower teachers to adopt new strategies in an authentic context without fear of real classroom consequences. This approach reinforces teachers' self-belief and cultivates a culture of risk-taking necessary for effective teaching.

However, implementing an AI-driven PD model is not without challenges, particularly in diverse contexts such as Minna, Nigeria. Critical issues include financial constraints, the availability of digital infrastructure, and varying levels of teacher digital literacy (Akgün & Greenhow, 2021). Furthermore, ethical considerations such as ensuring data privacy and the responsible use of AI technologies must be addressed (Balta, 2023). Establishing a strong support system will be vital for the successful integration of AI in teacher PD and for enhancing teachers' confidence and skills in using these technologies effectively.

Conclusion and Recommendations

The author hereby conclude that AI represents a paradigm shift for achieving the goals of effective PD among the outlined framework addresses longstanding challenges of traditional models by enabling personalised, contextually relevant, and dynamic learning experiences that foster both PCK and efficacy in teachers.

Recommendations

To propel this initiative forward, specific recommendations given as follows:

1. Policymakers should invest in pilot programmes that explore AI-driven PD amo alongside necessary infrastructural enhancements. Creating an environment conducive to technology integration will directly benefit educators and students.
2. Professional development provider should collaborate with AI developers to curate content that is relevant and sensitive to the contextual limitations faced by teachers, such as those in Nigeria. Tailoring PD resources to local needs will enhance their effectiveness and adoption.

3. School Administrators should foster a culture of innovation within schools. Administrators should allocate time and resources for teachers to engage with new AI-PD models, embracing an ethos of continuous improvement and learning.

In closing, the integration of AI into teacher professional development presents unprecedented opportunities to create a skilled and innovative teaching workforce. Aligning with the conference theme, this new frontier in educational technology heralds a transformative movement towards enhancing teaching quality and student outcomes, fundamentally reshaping the landscape of mathematics education.

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CONCEPTUAL REVIEW ON THE ROLE OF ARTIFICIAL INTELLIGENCE IN ENHANCING TEACHING AND LEARNING IN INDUSTRIAL AND TECHNOLOGY EDUCATION PROGRAMMES IN NIGERIA

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Abstract

This conceptual paper used a systematic literature review method to unveil the role of Artificial Intelligence (AI) in enhancing teaching and learning in Industrial and Technology Education (ITE) programmes in Nigeria. The paper established the crucial role of ITE programme in preparing youths for employment in five specific occupational areas in Nigeria. The concept of Artificial Intelligence, teaching and learning was reviewed. The key aspects of teaching and learning in the era of AI was also highlighted. The branches of AI were also unveiled. The concept of basic AI literacy was discussed extensively alongside the components of basic AI literacy. The paper went further to unveiled some selected empirical evidences of AI Applications in the field of education. The possible benefit of AI literacy in teaching and learning in Industrial and Technology Education programmes was highlighted. The paper concluded by highlighting the challenges and considerations for the ethical adoption of AI in the field of Industrial and Technology Education in Nigeria.

Keywords: *Artificial Intelligence, Teaching, Learning, AI Literacy, Industrial and Technology Education.*

Introduction

Industrial and Technology Education (ITE) programme is a programme designed to train Vocational and Technical teachers to teach effectively in Technical Vocational Education and Training (TVET) institutions as well as to function effectively as skilled technicians in the industries. The Federal Republic of Nigeria in her National Policy on Education (FRN, 2014) described TVET as a comprehensive term referring to those aspects of the educational process involving, in addition to general education, the study of technologies and related sciences and the acquisition of practical skills, attitudes, understanding and knowledge relating to occupations in various sectors of economic and social life. Specifically, the National Policy on Education (FRN, 2014) stated that the goals of TVET shall be to: provide trained manpower in the applied sciences, technology and business particularly at craft, advanced craft and technical level; provide the technical knowledge and vocational skills necessary for agricultural, commercial and economic development; and give training and impart the necessary skills to individuals who shall be self-reliant economically. The TVET teachers are basically trained through the Industrial and Technology Education (ITE) programme.

The aim of establishing ITE programme is to train individuals to equip them with teaching skills and technical skills in specific occupational area of specialization to enable them function effectively as Vocational and Technical teachers at TVET institutions (technical colleges,

vocational schools, training centers among others) as well as skilled technical personnel in industries. One of the objectives of the ITE programme is to produce qualified skilled technical teachers to enhance implementation of effective TVET programmes in Nigeria. The specific occupational area of specialization covered by ITE programme in most tertiary institution in Nigeria include: Automobile Technology, Building Technology, Electrical / Electronics Technology, Metalwork Technology as well as Woodwork Technology. The ITE programme is called different names depending on the institution such as Vocational and Technical Education or Technology Education. Despite the change in nomenclature from one higher institution to the other, the basic objectives of the programme remain the same.

Specifically, the objectives of the ITE programme according to ITE Departmental Handbook of Federal University of Technology (FUT)(2023) are to:

1. Develop a department of repute for training graduate and postgraduate students that are employable, enterprising and self-reliant.
2. Equip students with appropriate techniques to solve problems affecting Industrial and Technology Education and Technological innovations.
3. Provide specialized training for technical teachers, curriculum developers and supervisors of technology education at all school levels.
4. Enable students acquire additional professional knowledge, skills and experience so as to be able to relate to others meaningfully.
5. Acquaint students with creative teaching strategies at the elementary, secondary and tertiary levels of education.
6. Contribute meaningfully to the multidisciplinary nature of Industrial and Technology Education.
7. Equip students with design and research skills.
8. Vigorously promote quality consultancy for excellent service delivery and generate funds.
9. Encourage staff and students of the department to be ICT compliant and for the programme to be ICT driven.

Achieving the laudable objectives of ITE programme demand the use of effective teaching and learning methodologies that are relevant in the 21st century learning environment.

Concept of Teaching and Learning in ITE Programmes in Nigeria

Achieving the national goals of TVET in Nigeria can only be possible when TVET programmes in Nigerian TVET institutions strongly focus on effective teaching and learning. Teaching is the process of transferring information from the teacher to the learner to facilitate desirable change in behaviour in the learner; while learning was defined by Onatere-Ubrurhe and Ubrurhe (2025) as a relatively permanent change in behaviour that occurs in a learner when the learner is exposed to some experiences or training. Teaching and learning are two activities that are geared towards the attainment of educational goals. According to Akpan (2023), teaching and learning refers to an organized instructional process that is consciously geared towards transforming and developing students' intellectual ability, skills, ethics and values to enable individuals function effectively and become self-reliant, at the same time contribute positively to societal development.

In the era of Artificial Intelligence (AI), the concept of teaching and learning in Industrial and Technology Education have shifted from the conventional teacher-centered learning toward

personalized learning, adaptive environments, and the enhancement of human capabilities rather than replacement (Adlawan, 2024)). AI facilitates this by providing intelligent tutoring systems, automated grading, and adaptive content, allowing for individualized learning at a student's own pace. For technical education specifically, AI can revolutionize skill-based learning by providing real-time feedback, creating interactive training simulations, and assisting in the development of ethical AI frameworks to ensure fair and accessible integration of smart teaching and learning options that can teach skills and significantly bridge skill gaps at a good pace.

Concept of Artificial Intelligence (AI) in Industrial and Technology Education

The meaning of the concept of Artificial Intelligence (AI) may vary from one field to another and can also be based on various perspective. Culican (2024) revealed that, according to the father of Artificial Intelligence, John McCarthy; it is “the science and engineering of making intelligent machines, especially intelligent computer programs”. Dawes (2023) defined Artificial Intelligence as a way of making a computer, a computer-controlled robot, or a software think intelligently, in the similar manner the intelligent humans think. Artificial Intelligence (AI) was also defined by Awofiranye (2024) as a branch of computer science that focused on creating the computers or machines as intelligent as human beings. Similarly, it was defined by Holmes and Tuomi (2022) as the science of making computer machine to think smart like humans.

It was further defined by Marr (2024) as the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable. AI is accomplished by studying how human brain thinks and how humans learn, decide, and work while trying to solve a problem, and then using the outcomes of this study as a basis of developing intelligent software and systems. From a business perspective, AI is a set of very powerful tools, and methodologies for using those tools to solve business problems. From a programming perspective, AI includes the study of symbolic programming, problem solving, and search (Akgun and Greenhow, 2022).

From the background above, it can be inferred that the concept of Artificial Intelligence (AI) in Industrial and Technology Education involves using intelligent systems to create learning experiences, personalize learning experiences, automate administrative tasks, and provide hands-on practical training for a future-ready skill workforce. AI offers benefits like adaptive learning systems and intelligent tutoring systems for personalized skill development, but also presents challenges related to data privacy, digital literacy, and the need for substantial financial investment to enhance data security. Successfully integrating AI requires developing ethical frameworks and providing teachers with adequate digital and financial support to ensure inclusive and effective AI-driven vocational and technical training.

Key Aspects of Teaching and Learning in the AI Era

Recent researches in teaching and learning unveiled keys aspects of teaching and learning in the era of AI application in enhancing knowledge and skill transfer as outlined below:

Key Aspects of Teaching in the AI Era: The aspects of teaching reviewed in this study are:

1. **Facilitator Role:** In the facilitator role, teachers and lecturer's role pass through a transition from traditional lecturers to facilitators and guides, focusing on higher-order thinking skills and the ethical application of AI in technical fields.
2. **Curriculum Design:** Technical educators must incorporate AI concepts, tools, and ethical guidelines into technical curricula, ensuring students are prepared for AI-driven workplaces.
3. **Data-Driven Instruction:** Teachers can use AI-driven analytics to understand individual student needs, identify learning trends, and make data-based decisions to improve instruction.

Key Aspects of Learning in the AI Era : The aspects of learning reviewed in this study are:

1. **Personalized Learning:** In personalized learning, AI tailors learning paths and content to each student's abilities and pace, creating a more efficient and engaging learning experiences to enhance learners learning engagement. AI-powered tools create learning experiences tailored to individual student needs, improving engagement and memorization.
2. **Adaptive Learning:** In adaptive learning, AI systems adjust content and pace in real-time based on student performance, providing continuous feedback and support.
3. **Enhanced Skill Development:** Through enhanced skill development, AI can provide virtual training environments, real-time feedback on technical tasks, and tools for developing specific skills more effectively.
4. **Focus on Critical Thinking:** Through critical thinking, students learn to leverage AI as a tool for problem-solving, data analysis, and creative tasks, fostering innovation and critical thinking rather than simple recall.

Branches of Artificial Intelligence

The list of branches of AI given by Mishra and Deep (2023) are as follows:

Logical AI: In this branch of AI, the general facts concerning a specific situation and its goals are all represented by sentences of some mathematical logical language. The program decides what to do by inferring that certain actions are appropriate for achieving its goals.

Search AI : In a search AI, Artificial Intelligence programs often examine large numbers of possibilities. For example, moves in a chess game and inferences by a theorem proving program. Discoveries are frequently made about how to do this more efficiently in various domains.

Pattern Recognition AI: Here, a program makes observations of some kind, it is often planned to compare what it sees with a pattern. For example, a vision program may try to match a pattern of eyes and a nose in a scene in order to find a face. More complex patterns are like a natural language text, a chess position or in the history of some event. These more complex patterns require quite different methods than do the simple patterns that have been studied the most.

Representation AI: In representation AI, usually languages of mathematical logic are used to represent the facts about the world.

Inference AI: This branch of AI is based on inferences inferred from some facts. The simplest kind of non-monotonic reasoning is default reasoning in which a conclusion is to be inferred by default. But the conclusion can be withdrawn if there is evidence to the divergent. For example, when we hear of a bird, we infer that it can fly, but this conclusion can be reversed when we hear that it is a penguin. It is the possibility that a conclusion may have to be withdrawn that constitutes the non-monotonic character of the reasoning. Normal logical reasoning is monotonic, in that the set of conclusions can be drawn from a set of premises, i.e. monotonic increasing function of the premises.

Epistemology AI: This is a branch of AI which focused on the study of the kinds of knowledge that are required for solving problems in the world.

Ontology AI: Ontology is a branch of AI that deals with the study of the kinds of things that exist. In AI the programs and sentences deal with various kinds of objects and we study what these kinds are and what their basic properties are.

Heuristics AI: A heuristic AI is a branch of AI that is concerned with the way of trying to discover something or an idea embedded in a program. The term is used variously in AI. Heuristic functions are used in some approaches to search or to measure how far a node in a search tree seems to be from a goal. Heuristic predicates that compare two nodes in a search tree to see if one is better than the other, i.e. constitutes an advance toward the goal, and may be more useful.

Genetic Programming AI: Genetic programming is an automated method for creating a working computer program from a high-level problem statement of a problem. Genetic programming starts from a high-level statement of ‘what needs to be done’ and automatically creates a computer program to solve the problem.

Concept of AI Literacy

Just as basic literacy and internet literacy have become essential skills in the modern world, AI literacy is now emerging as a crucial competency. As artificial intelligence increasingly influences our daily lives, shaping everything from the media we consume to the decisions made in healthcare and finance, understanding AI is no longer optional. AI literacy is not a one dimensional skill; it is a multifaceted ability that touches on the technical, practical, and ethical elements of AI.

According to the European Union AI Act (EUAIA)(2024) the term AI literacy is the ability to grasp basic AI concepts, efficiently use AI tools, critically assess AI-generated outputs, understand the responsible use of AI, and stay adaptable in a rapidly evolving digital landscape. This definition of AI literacy comprises five core components: Foundational Knowledge of Basic AI Concepts, Practical Proficiency in AI Technologies, Critical Evaluation of AI Outputs, Responsible Use of AI, and Continuous Learning and Adaptability. Together, these elements ensure individuals are well-prepared to engage with AI responsibly and confidently.

Components of Basic AI Literacy

1. **Foundational Knowledge of Basic AI Concepts:** Much like how traditional literacy begins with understanding letters and words, AI literacy starts with a grasp of core AI concepts. This involves knowing what AI is, how it works, and its fundamental building blocks, such as algorithms, machine learning, and data processing interacts. Just as internet users needed to know about a browser or website to navigate online, today's AI-literate individuals need to know what AI is, how it learns from data, and what types of AI are at play at a particular point in time.

Example: Knowing what AI is, how it learns from data, and recognizing the different types of AI technologies is similar to understanding how the internet connected people through a network of computers. Without this foundational knowledge, deeper engagement with AI is impossible. This knowledge is universal because AI is being used globally, across industries and sectors, and understanding its core functions is essential for everyone, regardless of their background.

2. **Practical Proficiency in AI Technologies:** Just as internet literacy involves the use of digital tools like search engines and social media, AI literacy requires practical skills in using AI-driven technologies. It also involves understanding the appropriate type of prompting for an AI system and the expected response per time. This means knowing how to interact with everyday AI tools whether it's voice assistants, chatbots, or AI features in productivity software and leveraging them to enhance efficiency and decision-making. AI proficiency is not just about knowing how to use these tools; it is about understanding how to apply them effectively. Example: Using AI-driven scheduling tools to manage tasks or AI-powered creative tools to enhance productivity mirrors how internet users once learned to navigate websites or send emails. These skills are scalable; where users can start small, perhaps with personal AI assistants and gradually build up to mastering more complex AI systems as they progress in applying AI to solve problems.
3. **Critical Evaluation of AI Outputs:** In the early days of the internet, a major challenge became evaluating the credibility of information found online. Today, we face a similar challenge with AI. How do we trust the output of AI systems? Critical thinking is vital in evaluating AI-generated content, understanding potential biases in AI decision-making, and questioning the reliability of outputs.

Critical evaluation involves questioning AI recommendations, recognizing potential biases in the algorithms, and understanding the limitations of AI systems. Without this skill, individuals risk placing too much trust in AI without considering its fallibility.

Example: When a recommendation engine suggests products or media, AI-literate users should be able to ask why certain options are presented, understanding that biases in the data could skew results. This is similar to how we learned to distinguish credible websites from unreliable ones on the internet. This capacity to think critically is vital in a world where AI is often seen as a "black box," allowing users to make informed, responsible decisions based on AI output.

4. **Responsible Use of AI :** As AI continues to reshape industries like employment, healthcare, and justice, being AI-literate means understanding its ethical, legal, and societal implications. This includes recognizing how AI can influence issues like personal privacy, data protection, and social equity. Much like how digital rights movements have advocated for data privacy and equitable access to the internet, AI literacy requires a deep understanding of the ethical risks involved, such as bias in hiring algorithms, surveillance, or breaches in privacy. Users need to be aware of how AI can be misused and how these risks are addressed through regulations like the EU AI Act. AI literacy also involves grasping the importance of transparency and accountability in AI, especially regarding data usage and privacy. Users must be aware of how AI can be misused, from mass surveillance to undermining privacy rights, and how regulatory frameworks like EU AI Act aim to mitigate these risks.

Example: Knowing how AI is used in screening job applications or making credit decisions is analogous to understanding how the internet enabled new forms of digital activism while also creating spaces for cybercrime and data breaches. This awareness ensures individuals engage with AI responsibly, recognizing its societal impacts and advocating for transparency and accountability.

5. **Continuous Learning and Adaptability:** If we look at digital literacy from about 20 years ago, the landscape has certainly evolved with the rise of smartphones, laptops, and tablets. However, the core concept of internet usage accessing information, communication, and digital services has remained largely consistent. The tools have advanced, but the foundation has stayed the same.

In contrast, AI literacy is advancing at a much faster pace. Just two years ago, AI tools were impressive but limited, perhaps capable of generating an image from a prompt in seconds. Today, AI can build entire virtual worlds or automate complex business processes with a single click, demonstrating its exponential growth. This rapid transformation requires users to continuously learn and stay updated with the latest AI advancements to remain effective and competitive.

Given AI's unprecedented pace of development, continuous learning becomes one of the most critical aspects of AI literacy. Individuals need to stay current with new tools, technologies, and ethical considerations to fully engage with AI's potential. Those who fail to adapt may find themselves outpaced by AI's progress.

Example: Initially, OpenAI's ChatGPT was known for generating text and images. However, with the release of o1-preview, the AI can now "think" before responding, tackling complex reasoning tasks and solving problems that require deep thought, like building entire digital systems or solving intricate logic puzzles. This rapid advancement highlights the importance of continuous learning to keep up with AI's fast evolution.

This need for ongoing learning ensures that AI literacy remains future-proof, allowing users to keep up with cutting-edge developments like AI-generated media, automation systems, or virtual environments. It's not just about knowing today's AI but about staying ready for tomorrow's breakthroughs.

Some Selected Empirical Evidences of AI Applications in the Field of Education

Research evidence showed that there are various applications of AI in the education field in the areas of : content design, content delivery, assessment, feedback and support.

1. **Content Design :** In terms of content design, AI can enable the designing of content which is friendly and flexible. According to Culican (2024), AI algorithms can scan large data to tap into the gaps thus creating content that is interesting and trendy. AI can also be used for making content including textbooks, personalized learning materials, and interactive courses according to the target audience. AI tools enable the development of educational material that is based on natural language processing capabilities thus ensuring material that is consistent, concise and grammatically correct (Dawes, 2023).
2. **Content Delivery:** In terms of delivery of contents, AI enables delivery of contents more efficiently and flexibly by substituting classroom instruction and providing support for students to learn from anywhere in the world at any time. In the future, AI systems might replace lecturers in some subjects. Currently, some educational programs are equipped with AI, and scaffolding students to learn basic skills. According to Fahimirad and Kotamjani (2018), classroom AI systems have a high capability to analyze multiple sources of data and compare those data to known patterns. They can recognize the source of problems and give guidance to lecturers to achieve more consistent outcomes across various classes (Chen *et al.*, 2020). In other words, the AI and teachers can work together to create the best delivery method for students with maximum positive outcomes. The benefits of using AI for delivering educational content include the provision of individualized and customized learning, and universal access for all students who may speak different languages or have some disability such as visual or hearing impairment (Marr, 2024). Furthermore, according to Dawes (2023), AI can be used to analyze advanced insights about how students are receiving educational delivery and making progress thus enabling a more personalized learning experience. Thus, it can be argued that AI-based education delivery is more learner-centric compared to the traditional method of educational delivery and is beneficial for learners as well as tutors.
3. **Assessment:** In terms of assessment, AI can enable automated assessment. For example, AI can automate grading homework and tests usually take a significant amount of time. AI automated grading can grade nearly fill-in-the-blank and all kinds of multiple-choice testing. However, essay-grading software is still in its early stages yet and it will be improved over the coming years. According to the European School Education Platform (ESEP)(2023), AI can be used by tutors to personalize assessment and provide timely feedback addressing individual learning needs. The benefit of AI in assessment is that it can reduce human subjectivity and time taken for assessment. Furthermore, Sarker (2022) suggested that AI use in educational assessment increases consistency, personalization, and scalability. The reported benefits of AI in educational assessment include the ability to analyze large data with multiple sources, individual consideration, and flexibility (Mishra and Deep, 2023).
4. **Feedback and Educational Support:** For feedback and educational support, it is generally agreed that for learners, timely, relevant, and objective feedback is very important. AI also has the potential to provide feedback that meets these criteria. The use of AI in providing feedback on student's assessments or work is already in use (Hooda, Rana, Dahiya, Rizwan

and Hossain, 2022). For example, some schools are employing AI systems to track and monitor students' progress and to notify tutors if there is an issue with students' performance. Some tutoring programs are based on artificial intelligence to help students through writing, basic mathematics, and other subjects (Leite and Blanco, 2020). These AI programs can instruct students only in basic subjects; however, these machines are not perfect for teaching high-order thinking and creativity to students. Furthermore, generative AI tools like ChatGPT or Microsoft Bing can provide customized and quick feedback on students' work. According to Mollick and Mollick (2023), AI is being used in providing feedback to students which is personalized and asks students to take a different perspective. However, the authors noted that AI-based feedback is limited in the sense that it cannot replace human-grounded knowledge that a teacher has about their students.

Possible Benefit of AI Literacy in Teaching and Learning in Industrial and Technology Education Programmes

The current trends in teaching and learning of technical knowledge and skills have changed the expectation of both learners and technical educators globally. The current rising demand for more skilled-graduates in the industry is creating more tension among technical educators globally. There is an urgent necessity for AI adoption in teaching and learning in ITE programme in Nigeria higher institutions. To meet up with the demand of teaching and learning in the 21st century, technical educators and lecturers in higher institutions must learn how to use AI powered systems to enhance teaching and learning of skills. According to Hooda *et al* , (2022), AI provide a lot of benefits to technical educators as outlined below:

1. **Personalized Learning Opportunities:** AI-powered tools can be used to create learning experiences tailored to individual student needs, improving engagement and memorization. It makes it possible to generate skilled-based content and experiences that meet industrial needs of learners in industrial and technology education programme.
2. **Adaptive Learning Opportunities:** AI powered systems have the ability to adjust learning content and pace in real-time based on student performance, providing continuous feedback and support.
3. **Intelligent Tutoring Systems:** AI tutors use virtual simulations and machine learning to offer specialized guidance and practice, particularly for technical and hands-on skills experiences.
4. **Automation of Tasks:** AI systems can be used to automate required tasks, automate grading, scheduling, and enrollment management, freeing up educators to focus more on direct student interaction.
5. **Workforce Readiness:** AI powered systems can be used to simulate industrial skills experiences to prepare learners for real work tasks in line with industrial needs. By simulating industry scenarios and predicting future workforce needs, AI helps train individuals for evolving job roles in the AI-centric economy.

6. **Enhanced Skill Development:** AI system can be used to provides customized and interactive training, especially valuable for skills requiring significant practice and precision.
7. **Improved Learning Outcomes:** AI-driven platforms can be used to analyze vast amounts of data to identify learning gaps and patterns, leading to more effective instructional methodologies.
8. **Increased Efficiency:** The automation role of AI system reduces the manual workload for educators and administrators, streamlining educational processes.
9. **Innovation in Pedagogy:** AI powered systems can be used to create and simulate teaching approaches. AI enables new ways to teach and assess complex skills, moving beyond traditional static models to dynamic, learner-centered systems.
10. **Revolutionizing Skill-Based Training:** AI enables the development of realistic, interactive simulations for hands-on technical training, enhancing practical skills acquisition.
11. **Bridging the Skills Gap:** By personalizing learning and providing targeted instruction, AI can help address skill gaps and prepare a workforce for evolving technological demands.
12. **Promoting Innovation Technology Application:** AI tools can assist technical students and professionals in designing, developing, and implementing new technologies, driving innovation within technical field.

Challenges and Considerations for the Adoption of AI in Industrial and Technology Education

The adoption of AI in the field of Industrial and Technology Education comes with some challenges as outlined below:

1. **Digital Divide:** Ensuring equitable access to AI-powered tools for all students and lecturers is crucial, as current systems may be inaccessible to those lacking digital capabilities.
2. **Ethical Frameworks:** The development and use of AI in education require careful consideration of moral frameworks to ensure fairness and prevent bias in AI application.
3. **Teacher Training:** Educators in Industrial and Technology Education programme need proper training and digital support to effectively implement and utilize AI technologies in their teaching practices.
4. **Data Privacy:** When the usage of AI involves collecting and analyzing student data; concern could be raise about data privacy and security of student's information.
5. **Cost and Infrastructure:** Implementing advanced AI systems requires substantial financial investment and advanced digital infrastructure, which may be a barrier for some institutions that lack adequate fund.

Training Implication of AI Adoption in Industrial and Technology Education in Nigeria

Based on the fast rate at which AI application is influencing teaching, learning and technological innovations globally, the researchers proposed a training implication to serve as a direction for training or guide to enhance the knowledge and skills of both students and lecturers in the adoption of AI in the field of Industrial and Technology Education in Nigeria.

1. Periodic training on the foundational knowledge of basic AI concepts and their application in problem solving.
2. Periodic training on practical proficiency in AI Technologies.
3. Periodic training on the critical evaluation of AI outputs.
4. Periodic training on the responsible use of AI tools and AI systems.
5. Periodic training on the continuous learning and adaptability of tools and systems.

Conclusion

This conceptual paper discussed the possible role of AI in the education field. The previous studies reviewed showed that the application of AI in the education field is changing the landscape of education in various aspects including approach to course plan development, delivery of courses, content creation and distribution, and so on. Studies reviewed also establish potential role of AI in enhancing more functional Industrial and Technology Education programme in Nigeria. Literature evidence shows that AI have the potential of empowering both the teaching staff and the students to become more in control by focusing on more important tasks while leaving the routine repeated simple tasks to the AI system. The key challenges we discussed included ethical issues related to AI in education, data privacy issues, as well as the cost involved in developing AI systems. From the literature evidence in this paper, It is worthy to establish that AI is revolutionizing the field of Industrial and Technology Education and is significantly improving the teaching and learning of technical knowledge and skills. Providing ethical standards for AI application in the field of Industrial and Technology Education will help improve the benefits of AI usage.

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RELATIONSHIP BETWEEN EMOTIONAL INTELLIGENCE AND CRITICAL THINKING SKILLS IN NORTH CENTRAL NIGERIA

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Abstract

This work evaluated relationship between emotional intelligence and critical thinking skills in Northcentral Nigeria. Two objectives, two research questions and one hypothesis guided the study. The study adopted correlational research design. The population for this study was pre-service science educators in federal universities in Northcentral Nigeria. The sample for this study was 274 using proportional sampling technique. The instrument for this study were emotional intelligence questionnaire and critical thinking skills questionnaire which were developed by researcher and validated by three experts across universities in Northcentral Nigeria. These instrument were pilot-tested on Pre-service science educators of University of Ilorin three hundred level and evaluated yielding 0.78 which believed reliable for the study. These instruments were used to collect data and the data were analyzed using Special package for social sciences (SPSS). The research questions were answered using descriptive statistics (mean, standard deviation and scatterplot while the hypothesis was tested using linear regression analysis. The results show that pre-service science educators possessed medium level of both critical thinking skills and emotional intelligence and strong relationship between emotional intelligence and critical thinking skills were also established. The study concluded that there is strong relationship between emotional intelligence and critical thinking skills based on this the study recommended that Teacher education institutions and colleges should embed structured emotional intelligence (EI) development programmes such as workshops on self-awareness, emotion regulation, empathy, and social skills into their curricula. Doing so may enhance critical thinking skills, which are central to effective teaching and learning, continuous professional development (CPD) for teachers should include modules on fostering both EI and critical thinking among students. Teachers with higher EI are better equipped to model reflective thinking and create emotionally supportive learning environments that promote critical inquiry.

Keywords: *Critical thinking skills, Emotional Intelligence, Pre-service Science Educators*

Introduction

in recent decades, emotional intelligence (EI) has emerged as a significant construct in educational psychology, organizational behaviour, and social sciences. Broadly, EI refers to the capacity to recognize, understand, regulate and utilize emotions effectively in oneself and others (Salovey & Mayer, 1990; Goleman, 1995). Unlike cognitive intelligence, which emphasizes analytical and problem-solving skills, EI underscores the non-cognitive abilities that contribute to interpersonal effectiveness, resilience and overall well-being. The increasing recognition of EI highlights its pivotal role in shaping academic performance, workplace success, leadership and personal development.

In educational contexts, EI has been linked to improved motivation, stress management, classroom relationships and enhanced learning outcomes (Sánchez-Álvarez *et al.*, 2020). Students with higher EI demonstrate stronger adaptability, better problem-solving skills, and greater

collaboration with peers, all of which are crucial in an era of learner-centered and blended pedagogies. Similarly, teachers with higher EI are better equipped to manage classroom challenges, foster inclusive learning environments, and support students' socio-emotional growth (Alrajhi *et al.*, 2021). These findings suggest that EI is not only complementary to cognitive ability but also essential in developing holistic learners who can thrive in diverse academic and social settings.

Moreover, the relevance of EI extends beyond the school environment. In the workplace, emotionally intelligent individuals show stronger leadership potential, conflict resolution ability and teamwork (Miao *et al.*, 2018). In today's rapidly changing and technologically driven society, where collaboration and adaptability are highly valued, EI has become indispensable. This has led to an increasing demand for integrating EI training into curricula at various educational levels to prepare students for both academic success and life beyond the classroom.

Despite its growing relevance, the incorporation of EI in education and training remains inconsistent, particularly in developing contexts where academic performance is often prioritized over socio-emotional learning. This gap underscores the need for empirical research to examine the effectiveness of EI in enhancing not only academic achievement but also critical skills such as motivation, resilience, and social adjustment. A deeper understanding of EI as a psychological and educational construct can provide useful insights for curriculum developers, educators, and policymakers.

Critical thinking (CT) has become one of the most essential skills in education and knowledge-based economies of the 21st century. It refers to the ability to actively and skillfully conceptualize, analyze, synthesize, evaluate, and apply information gathered from observation, experience, or reasoning as a guide to belief and action (Facione, 2020). Unlike rote memorization, CT emphasizes reflective judgment, problem-solving, creativity and the capacity to make sound decisions in complex situations. As global challenges become increasingly interconnected, education systems are shifting from the mere transmission of facts to cultivating higher-order thinking skills, among which CT is central.

In educational settings, critical thinking skills (CTS) are strongly associated with deeper learning, improved problem-solving ability, and greater academic achievement (Choy & Oo, 2021). Students with well-developed CTS can evaluate evidence, detect inconsistencies, and approach problems from multiple perspectives, thereby enhancing their independence and lifelong learning capacities. For educators, fostering CT enables them to create inquiry-driven learning environments where learners are encouraged to question, reflect, and engage in meaningful dialogue (Widyastono, 2022).

Globally, curriculum reforms emphasize the integration of CTS as part of 21st-century competencies. The UNESCO Education 2030 Agenda underscores CT as vital for preparing learners to become active, responsible citizens capable of addressing social, environmental, and technological challenges. In line with this, researchers have argued that the infusion of CT into teaching and learning processes not only strengthens academic knowledge but also equips learners with the resilience, adaptability, and innovation skills needed in modern workplaces (Rizwan *et al.*, 2023).

Despite its recognized importance, developing CT among learners remains a challenge. Many instructional practices, especially in developing countries, are still dominated by teacher-centered approaches that prioritize memorization and recall over inquiry and reasoning (Adeyemi & Adesoji, 2020). This pedagogical gap often results in learners lacking the ability to apply knowledge beyond examinations. Consequently, there is an increasing call for instructional innovations such as problem-based learning, blended learning, inquiry-based strategies, and the use of technology to foster CTS in diverse learning contexts.

Thus, the study of CT is not only timely but also essential for bridging the gap between traditional instructional practices and the demands of 21st-century education. By examining how CTS can be cultivated within specific disciplines, educators and policymakers can design strategies that promote active, reflective, and meaningful learning.

The 21st-century learning landscape emphasizes not only cognitive competencies but also socio-emotional capacities that collectively shape holistic education. Emotional intelligence (EI) and critical thinking skills (CTS) are two interrelated constructs that have gained prominence in education, psychology and leadership research. EI refers to the ability to recognize, regulate, and utilize emotions constructively (Goleman, 1995), while CT involves the disciplined process of analyzing, evaluating, and synthesizing information to make informed decisions (Facione, 2020). Though often treated as separate domains, emerging studies show that EI and CTS are closely connected and mutually reinforcing in enhancing learners' academic and life outcomes.

Emotional intelligence provides the affective foundation upon which critical thinking can be effectively exercised. For example, individuals who can manage stress, control impulsivity and regulate emotional biases are better positioned to engage in reflective judgment and rational decision-making (Hasanzadeh & Shahmohamadi, 2021). Similarly, empathy and social awareness components of EI foster open-mindedness and tolerance for diverse perspectives, which are critical dispositions for engaging in higher-order thinking (Tican & Deniz, 2019). In this way, EI enhances learners' readiness to apply CTS in problem-solving and inquiry.

Conversely, strong critical thinking enables individuals to evaluate emotional responses, question assumptions and apply logic to emotionally charged situations. This balance between affect and cognition is essential in contemporary education, where learners must navigate complex academic tasks and social challenges. Research has suggested that students with higher EI and CTS not only achieve better academically but also demonstrate improved teamwork, resilience and adaptability in changing learning environments (MacCann et al., 2020).

In educational practice, the integration of EI and CTS has significant implications. Learners equipped with both constructs are more likely to manage academic stress, engage in collaborative inquiry and sustain motivation in blended and inquiry-based classrooms. Yet, in many developing contexts, instructional methods remain predominantly teacher-centered, with limited attention to socio-emotional learning. This gap highlights the need to foster both EI and CTS simultaneously to prepare learners for the cognitive and emotional demands of 21st-century education and beyond.

Purpose of the Study

The aim of this study is to determine relationship between emotional intelligence and critical thinking skills in northcentral Nigeria: The following objectives will guide the study:

1. Determine the level of emotional intelligence of pre-service science educators in the Northcentral Nigeria
2. Determine the relationship between emotional intelligence and critical thinking skills

Research Questions

1. What is the level of emotional intelligence of pre-service science educator in Northcentral Nigeria
2. What is the relationship between emotional intelligence and critical thinking skills

Research Hypothesis

H0₁ ; There is no significant difference in relationship between emotional intelligence and critical thinking skills

Methodology

This work adopted correlational research design. The population for this study is all science educators in North-Central Nigeria which comprises of seven state that is Benue State, Kwara State, Kogi State, Nasarawa State, Plateau State and Federal Capital Territory Abuja (FCT, Abuja). The sample for this work was 274 using slovin formular. The instrument used to collect data are five likert scale emotional intelligence questionnaire and critical questionnaire rated strongly agreed (SA), Agreed (A), Disagreed (D), Strongly Disagreed (SD) and Neutral. The instruments were validated by three experts one from department of Education foundation Ibrahim Babangida University, one from Industrial Technology Education, Federal University of Technology and Department of science education federal university of technology Minna Niger State. The reliability of these have been determined using cronbach alpha which yielded 0.72 and 0.89. The data was collected using these instruments. The data collected were analyzed using descriptive and inferential statistics. The research questions were answered using mean, standard deviation, scatterplots and hypotheses was tested using regression analysis.

Results:

Research Question One: What is the level of emotional intelligence of university pre-service science educators in Northcentral Nigeria

Table 1.1 Mean and Standard Deviation of Emotional Intelligence of Pre-service Science Educators in Northcentral

Items	Mean	STD	Decision
I always I understand my feeling during class lectures	2.90	.62	Moderate
I realize the links between my feeling and what I think, do , and say	2.71	.49	Moderate
I am aware of my values and goals in the school	2.74	.49	Moderate

I cannot explain why I feel anxious in the school	2.97	.49	Moderate
I do not realize the links between feeling and what I think, do and say	2.76	.48	Moderate
I guide the performance of other while holding them accountable	2.58	.49	Moderate
I consciously change my mood to adjust in the school environment	2.74	.47	Moderate
I continuously learn in order to improve my performance	2.94	.47	Moderate
I adept well to unexpected changes in my academic schedule	2.81	.48	Moderate
I cannot guide the performance of others while holding them accountable	2.70	.46	Moderate
Motivation has been the key to my academic success	2.80	.49	Moderate
I derive joy in pursuing my school goals	2.74	.49	Moderate
I derive joy in planning my school activities	2.62	.49	Moderate
I can motivate myself even when I failed my exams	2.92	.49	Moderate
I do not derive joy in pursuing my school goal	2.59	.49	Moderate
	2.77	.51	Moderate
I read the signs if my classmate are upset	2.82	.49	Moderate
I can change my mood to adjust in the school environment	2.88	.50	Moderate
I am aware of unspoken rules and social dynamic within my department	2.79	.50	Moderate
I can sense the mood in the lecture hall or study group	2.78	.50	Moderate
I cannot change my mood to adjust in the school environment			

The table 1.1 shows the descriptive statistics of (EI) among university pre-service science educators in Northcentral Nigeria. Based on the descriptive statistics, the respondents' emotional intelligence is uniformly situated at a moderate level across all measured indicators (grand mean = 2.77, SD = 0.51).

The moderate means for items such as "I always understand my feeling during class lectures" (M = 2.90, SD = 0.62) and "I realize the links between my feeling and what I think, do, and say" (M

= 2.72, SD = 0.49) suggest that participants possess fair self-awareness but may not consistently engage in deep reflection on emotional experiences. Their awareness of values and goals in the school context (M = 2.74, SD = 0.50) similarly points to a middling degree of emotional insight into their professional aspiration.

In the domain of self-regulation, items such as “I consciously change my mood to adjust in the school environment” (M = 2.74, SD = 0.48) and “I adapt well to unexpected changes in my academic schedule” (M = 2.81, SD = 0.49) again fall within the moderate range. This indicates that while the respondents do attempt to regulate their emotional states, their flexibility and consistency in doing so may be limited under pressure or unfamiliar contexts.

Regarding motivation, statements like “I can motivate myself even when I failed my exams” (M = 2.92, SD = 0.50) and “Motivation has been the key to my academic success” (M = 2.80, SD = 0.49) reflect a comparatively stronger but still moderate disposition toward intrinsic drive. Their ability to sustain efforts despite setbacks seems one of the relatively stronger facets of their emotional intelligence.

When it comes to social awareness (empathy), pre-service educators responded at moderate levels on items such as “I read the signs if my classmate are upset” (M = 2.82, SD = 0.49) and “I can sense the mood in the lecture hall or study group” (M = 2.78, SD = 0.50). This suggests some ability to detect emotional cues among peers, though not with strong consistency or confidence.

Finally, in relationship management, the relatively lower means recorded (e.g. “I guide the performance of others while holding them accountable,” M = 2.58, SD = 0.49; “I do not realize the links between feeling and what I think, do and say,” M = 2.76, SD = 0.48) imply that participants are less comfortable or adept in influencing others’ emotional states and holding them responsible in a relational context. Overall, no dimension of the emotional intelligence scale reached a high (strong) level; all are solidly in the medium band. This uniformity suggests that pre-service science educators in this region maintain an average emotional intelligence profile characterized by fair self-insight, regulation, empathy, motivation, and relational competence.

In answer to the research question “What is the level of emotional intelligence of pre-service science educators in Northcentral Nigeria”? the current study demonstrates that their emotional intelligence is at a moderate (medium) level across all measured dimensions. While their self-motivation and social sensitivity are neither poor nor exceptional, the modest levels in self-regulation and relationship management suggest areas for targeted development. To optimize their future professional effectiveness, teacher preparation programmes should integrate structured emotional intelligence-building components.

Research Question Two: What is the relationship between emotional intelligence and critical thinking skills To test the relationship emotional intelligence and critical thinking skills scatterplot was carried out as shown in figure 1.1

Scatterplot of Emotional Intelligence and Critical Thinking Skills

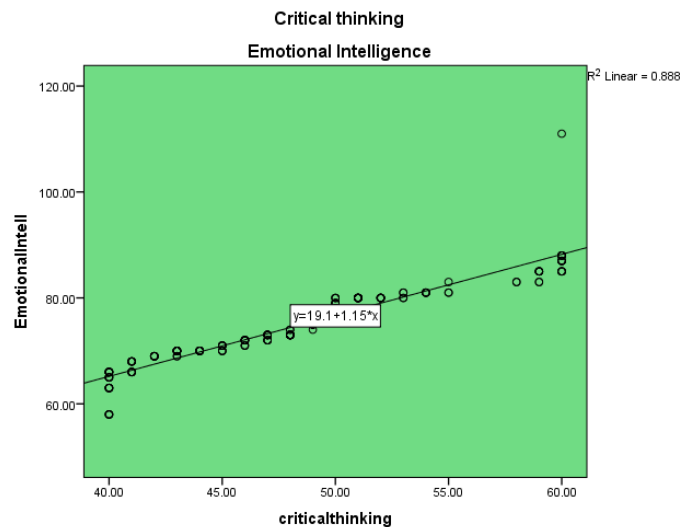


Figure 1.1: Scatterplot of Emotional Intelligence and Critical Thinking Skills

The scatterplot figure 1.1 shows a strong positive linear relationship between critical thinking and emotional intelligence. The regression equation is: {Emotional Intelligence} = 19.1 + 1.15{Critical Thinking}. This means that for every 1-unit increase in critical thinking, emotional intelligence increases by about 1.15 units. The $R^2 = 0.888$, indicating that about 88.8% of the variance in emotional intelligence is explained by critical thinking, a very strong relationship.

The data points are tightly clustered around the regression line, showing a very strong and consistent trend. The spread looks fairly even across the range of critical thinking scores, which suggests homoscedasticity (no major changes in spread as values increase). This supports the reliability of the regression model. Most points follow the upward trend, but there is one potential outlier at the upper-right corner: a case where emotional intelligence is unusually high compared to the predicted value. While it does not distort the overall pattern significantly, it is worth checking if this case represents a special condition or measurement anomaly. The scatterplot reveals a strong positive linear relationship between critical thinking and emotional intelligence. As critical thinking increases, emotional intelligence also increases substantially, with an R^2 of 0.888 showing that nearly 89% of the variation in emotional intelligence is explained by critical thinking. The distribution of points is tightly aligned with the regression line, suggesting a robust model. However, one outlier exists with exceptionally high emotional intelligence, which may need further investigation.

Hypothesis

There is no significant relationship between emotional intelligence and critical thinking skills. To test this hypothesis, linear regression analysis was carried out as shown in table 1.1, 1.2 and 1.3.

Table 1.1 Model Summary of Linear Regression Analysis

Model	R	R SQUARE	Adjusted R SQUARE	Std Error of Estimate	R Square Change	F Change	Df1	Df2	Sign F change	Durbin Watson
1	.942	.888	.887	1.93928	.888	1560.051	1	270	.000	.505

A simple linear regression was conducted to examine whether emotional intelligence significantly predicts critical thinking. Results revealed that the model was statistically significant, $F(1, 270) = 1560.05$, $p < .001$, with emotional intelligence accounting for approximately 88.8% of the variance in critical thinking ($R^2 = .888$, Adjusted $R^2 = .887$). The regression coefficient indicated a strong positive relationship ($R = .942$), suggesting that higher levels of emotional intelligence are associated with higher levels of critical thinking. The standard error of the estimate was 1.94, indicating relatively small prediction errors. However, the Durbin–Watson statistic was .505, which falls below the acceptable range of 1.5 to 2.5. This suggests the presence of positive autocorrelation among residuals, potentially violating the assumption of independence of errors.

Table 1.2 ANOVA Table Linear Regression Analysis of Emotional Intelligence and Critical Thinking Skills

Model	Sum of Squares	df	Mean Square	F	Sign
Regression	5867.077	1	5867.077	1560.051	.000 ^b
Residual	740.882	197	3.761		
Total	6607.960	198			

An ANOVA was performed to assess whether the regression model significantly predicted critical thinking from emotional intelligence. Results indicated that the model was statistically significant, $F(1, 197) = 1560.05$, $p < .001$, accounting for a substantial portion of the variance in critical thinking. This suggests that emotional intelligence is a significant predictor of critical thinking.

Table 1.3 Linear Regression Coefficients of Emotional Intelligence and Critical Thinking Skills

Predictor Partial Part	B (Unstd.)	Std. Error	Beta (Std.)	T	Sig.	95% CI for B	Zero- order
Constant (Intercept)	-9.311	1.463		-6.366	.000	-12.195, - 6.427	
EmotionalIntell	.771	0.020	.942	39.497	.000	0.732, 0.809	.942

The regression coefficients indicated that emotional intelligence was a significant predictor of critical thinking. Specifically, emotional intelligence had a strong positive effect, $B = 0.77$, $SE = 0.02$, $\beta = .94$, $t(197) = 39.50$, $p < .005$, with a 95% confidence interval[0.73, 0.81]. This suggests that for each one-unit increase in emotional intelligence, critical thinking scores increased by approximately 0.77 units. The regression equation is: $\{Y\} = -9.31 + 0.77X$

Where Y represents critical thinking and X represents emotional intelligence.

A simple linear regression was conducted to examine whether emotional intelligence significantly predicts critical thinking.

The model was statistically significant and demonstrated a very strong predictive relationship between emotional intelligence and critical thinking. The results showed that emotional intelligence accounted for approximately 88.8% of the variance in critical thinking, $R^2 = .888$, Adjusted $R^2 = .887$, with a strong correlation coefficient ($R = .942$). The standard error of the estimate was 1.94, indicating relatively small prediction errors. However, the Durbin–Watson statistic was .505, suggesting positive autocorrelation of residuals,

The ANOVA test further confirmed the statistical significance of the regression model, $F(1, 197) = 1560.05$, $p < .001$, indicating that emotional intelligence provides a significant improvement in predicting critical thinking compared to a model without predictors. The coefficients table revealed that emotional intelligence was a significant positive predictor of critical thinking, $B = 0.77$, $SE = 0.02$, $\beta = .94$, $t(197) = 39.50$, $p < .001$, with a 95% confidence interval $[0.73, 0.81]$. This means that for every one-unit increase in emotional intelligence, critical thinking increased by approximately 0.77 units. The regression equation can be expressed as: $\{Y\} = -9.31 + 0.77X$ where $\{Y\}$ represents the predicted critical thinking score and X represents emotional intelligence. Therefore this hypothesis is rejected and alternate hypothesis is retain which say there is significant relationship between emotional intelligence and critical thinking skills of science educators in Northcentral of Nigeria.

The present study examined whether emotional intelligence (EI) predicts critical thinking (CT). The regression model showed a very strong positive association: emotional intelligence significantly predicted critical thinking, $B = 0.77$, $SE = 0.02$, $\beta = .94$, $t(197) = 39.50$, $p < .001$, and the model accounted for 88.8% of the variance in critical thinking ($R^2 = .888$). These results indicate that higher EI scores were associated with substantially higher CT scores in this sample.

This finding is consistent with recent empirical evidence that emotional competencies are closely tied to cognitive outcomes. Meta-analytic and review-level evidence indicates that EI is positively related to academic and cognitive performance, although effect sizes vary by context and measure (Sánchez-Álvarez *et al.*, 2020; Quílez-Robres *et al.*, 2023). In more targeted studies, researchers have reported positive correlations between EI (or its facets) and CT disposition among students in applied fields such as nursing and teacher education (Hasan *et al.*, 2024; Quílez-Robres *et al.*, 2021).

Mechanistically, the link between EI and CT can be interpreted in light of theories suggesting that emotion regulation and affective awareness free up cognitive resources for higher-order reasoning, individuals who recognize and manage emotions can better sustain attention, evaluate alternative perspectives and engage in reflective thinking processes central to CT. Empirical studies support this mechanism by showing that EI, especially emotion-management branches, predicts wise or reflective reasoning and other cognitive outcomes (Iqbal *et al.*, 2021; Schneider *et al.*, 2021). Thus, the present strong effect ($\beta = .94$) aligns with theoretical expectations that EI facilitates complex cognitive processing in educational contexts.

Implications: Practically, the results suggest that interventions aimed at developing EI may have beneficial downstream effects on students' CT skills important for curricula in teacher education, nursing, and other professional programmes where both affective and cognitive competencies are essential. This supports calls for integrated training that simultaneously targets emotion regulation, reflective practice and analytical reasoning to strengthen clinical judgment and educational outcomes (Quílez-Robres *et al.*, 2023; Hasan *et al.*, 2024).

Conclusion. In sum, the regression results demonstrate a robust positive association between EI and CT. The finding aligns with recent empirical and meta-analytic work suggesting EI contributes to academic and cognitive outcomes. However, the low Durbin–Watson statistic and the cross-sectional design counsel caution. Addressing model diagnostics and testing causal mechanisms should be priorities for subsequent research and for translating these findings into effective educational practice.

Recommendations: Based on the findings that emotional intelligence strongly and positively predicts critical thinking, the following recommendations are proposed:

1. Teacher education institutions and colleges should embed structured emotional intelligence (EI) development programmes such as workshops on self-awareness, emotion regulation, empathy, and social skills into their curricula. Doing so may enhance critical thinking skills, which are central to effective teaching and learning
2. Continuous professional development (CPD) for teachers should include modules on fostering both EI and critical thinking among students. Teachers with higher EI are better equipped to model reflective thinking and create emotionally supportive learning environments that promote critical inquiry.
3. Education policymakers should recognize the importance of EI as a determinant of cognitive outcomes. Policy frameworks could mandate the inclusion of EI-focused pedagogical strategies in teacher education programs to improve overall educational quality and student outcomes
4. School counselors and psychologists should design interventions that simultaneously target emotional regulation and cognitive development. Such dual interventions could foster resilience, enhance decision-making, and strengthen critical reasoning skills in learners.

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AWARENESS AND ADOPTION OF ARTIFICIAL INTELLIGENCE TOOLS FOR BUILDING PROJECT MANAGEMENT AMONG ARCHITECTS AND BUILDERS IN FEDERAL CAPITAL TERRITORY, ABUJA, NIGERIA

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Abstract

The study determine the level of awareness and extent of adoption of AI tools for building project management among architects and builders in FCT Abuja. Two research questions guided the study. A descriptive survey design was used for the study. The targeted population of the study was 312 respondents comprising of 148 registered architects and 164 registered builders in FCT Abuja. A 24 items structured questionnaire validated by three experts was used for data collection. To establish reliability, a pilot test was conducted in Minna, Niger State, involving six builders and four contractors. Using Cronbach's Alpha statistical technique, the overall reliability coefficient of the instrument was found to be 0.86. Data collected were coded and analyzed using the Statistical Package for Social Sciences (SPSS, Version 27). Mean and standard deviation were employed to answer the research questions. The findings of the study revealed that architects and builders in FCT Abuja are slightly aware of AI tools for building project management with a grand mean ($\bar{X} = 2.28$). The findings also revealed that the extent of adoption of AI tools for building project management among architects and builders in FCT Abuja was low with a grand mean ($\bar{X} = 1.73$). Based on the findings, it was recommended among others that professional development programmes, workshops and seminars should be organized for architects and builders in FCT Abuja to increase their awareness and understanding of AI tools and that construction firms, professional bodies and government agencies should provide the necessary infrastructure, technical support, and incentives to encourage the adoption of AI technologies.

Keywords: Awareness, Adoption, Artificial Intelligence Tools, Building Project Management, Architects, Builders

Introduction

Artificial Intelligence (AI) refers to computer systems or technologies designed to perform tasks that typically require human intelligence, such as learning, reasoning, problem-solving, decision-making, and pattern recognition. AI encompasses a range of technologies, including machine learning, natural language processing, expert systems, and computer vision, which enable machines to analyze large data sets, generate predictions, and automate complex processes (Russell & Norvig, 2021). In recent years, AI has gained widespread adoption across industries such as healthcare, finance, manufacturing, and education due to its ability to improve efficiency, accuracy, and productivity.

Building project management, on the other hand, is the process of planning, coordinating, and controlling construction projects from inception to completion within specified cost, time, and quality parameters (Kerzner, 2017). It requires the integration of diverse professional inputs from

architects, builders, engineers, and other stakeholders to achieve successful project delivery. In this context, AI tools are increasingly being applied to project management tasks such as scheduling, cost estimation, design optimization, risk analysis, resource allocation, and progress tracking (Wunderbuild, 2025; Cheche, *et al*, 2024). For instance, AI-powered Building Information Modeling (BIM) systems, generative design platforms, and predictive analytics tools are now being used to enhance decision-making, reduce delays, and minimize cost overruns in construction projects worldwide. The construction sector in Nigeria, plays a critical role in economic growth and infrastructure development. However, it faces persistent challenges such as cost overruns, delays, low productivity, and limited adoption of modern technologies (Owolabi *et al.*, 2022).

The integration of AI tools into building project management has the potential to address some of these challenges by improving efficiency, transparency, and collaboration among professionals. Studies have shown that many construction professionals in Nigeria are aware of AI applications in areas such as BIM, scheduling, and cost management, yet the actual level of adoption remains low due to factors like high cost of technology, lack of technical skills, resistance to change, and infrastructural limitations (Cheche, *et al*, 2024; Akwaowo, *et al.*, 2024). Despite the growing global evidence of AI's transformative potential, there is limited empirical research focusing on the level of awareness and extent of adoption of AI tools among specific professional groups in building construction industry in Nigeria. In FCT Abuja, which serves as a hub for architectural and building practices, the integration of AI into project management appears to be underexplored. Determining how aware architects and builders are of AI tools, and to what extent they adopt them, was crucial for guiding training, professional development, and policy interventions. This study therefore sought to determine the level of awareness and extent of adoption of AI tools for building project management among architects and builders in FCT Abuja.

Statement of the Problem

Building project management is expected to ensure that construction projects are delivered within stipulated time, cost, and quality standards. The integration of advanced technologies such as AI tools has the potential to make this possible by automating scheduling, enhancing cost estimation, predicting risks, and improving coordination among project stakeholders (Russell & Norvig, 2021; Kerzner, 2017). Across the globe, AI-enabled Building Information Modeling (BIM), predictive analytics, and automated monitoring systems are increasingly being applied to improve efficiency, minimize errors, and support data-driven decision-making in project management (Wunderbuild, 2025).

However, building project management in Nigeria continues to face persistent challenges such as delays, cost overruns, and inefficient resource utilization (Owolabi *et al.*, 2022). Although professionals are becoming increasingly aware of AI and its applications, the extent of adoption in project management remains very limited. Factors such as high implementation costs, inadequate technical expertise, poor digital infrastructure, and resistance to organizational change have slowed the uptake of AI technologies within the construction industry (Cheche *et al.*, 2024; Akwaowo *et al.*, 2024). As a result, many building projects in the FCT Abuja still depend largely on traditional project management methods, which are often less effective in handling the growing complexity of modern construction projects. This continued reliance undermines the ability of professionals to deliver projects in an efficient, competitive, and sustainable manner. Against this backdrop, the

present study sought to determine the level of awareness and extent of adoption of AI tools for building project management among architects and builders in FCT Abuja.

Aim and Objectives of the Study

The aim of the study is to determine the level of awareness and extent of adoption of artificial intelligence tools for building project management among architects and builders in FCT, Abuja, Nigeria. Specifically, the objectives are to determine:

3. the level of awareness of AI tools for building project management among architects and builders in FCT Abuja
4. the extent of adoption of AI tools for building project management among architects and builders in FCT Abuja

Research Questions

The following research questions were raised to guide the study:

3. What is the level of awareness of AI tools for building project management among architects and builders in FCT Abuja?
4. What is the extent of adoption of AI tools for building project management among architects and builders in FCT Abuja?

Methodology

A descriptive survey research design was adopted for this study. This design was considered appropriate because it allows for the systematic collection of data from a defined population through the use of structured questionnaires, thereby enabling the researcher to describe, analyze, and generalize findings to the larger population (Fraenkel *et al.*, 2019). The targeted population of the study was 312 respondents comprising of 148 registered architects and 164 registered builders in FCT Abuja. The instrument for data collection was a structured questionnaire titled: “*Awareness and Adoption of Artificial Intelligence Tools for Building Project Management Questionnaire (AAAITBPMQ)*”, developed by the researcher. The instrument contained 24 items and was structured on a four-point rating scale of: Highly Aware (HA = 4), Moderately Aware (MA = 3), Slightly Aware (SA = 2) and Not Aware (NA = 1) for research question one and Very High Extent (VHE = 4), High Extent (HE = 3), Moderate Extent (ME = 2) and Low Extent (LE = 1) for research question two. The instrument was subjected to face validation by three experts in the Department of Industrial and Technology Education, Federal University of Technology, Minna, Niger State. To establish reliability, a pilot test was conducted in Minna, Niger State, involving six builders and four contractors. The internal consistency of the instrument was determined using Cronbach’s Alpha, which yielded coefficients of 0.83 and 0.81 for the two sections, respectively. The overall reliability coefficient of 0.86 confirmed that the instrument was both reliable and suitable for use. The questionnaires were administered by the researcher with the support of trained research assistants through direct delivery and retrieval methods to ensure a high response rate. Data collected were coded and analyzed using the Statistical Package for the Social Sciences (SPSS, Version 27). Mean and standard deviation were employed to answer the research questions.

Research Question 1: What is the level of awareness of AI tools for building project management among architects and builders in FCT Abuja?

The data for answering research question one is presented in Table 1.

Table 1: Mean and Standard Deviation of Respondents on the Level of Awareness of AI Tools for Building Project Management

S/N	Items	Mean ($\bar{x}$) (N = 312)	SD	Remark
1	I am aware of AI-enabled BIM for project design coordination.	3.63	0.44	HA
2	I am aware of AI tools used for project scheduling and time management optimization	2.32	0.65	MA
3	I am aware of AI applications that support cost estimation and budget control in projects	2.65	0.55	MA
4	I am aware of AI-driven predictive analytics for risk identification and management	1.40	0.79	NA
5	I am aware of AI applications for construction site monitoring and safety management	3.08	0.59	MA
6	I am aware of AI-powered tools for resource allocation and optimization in building projects	2.42	0.72	SA
7	I am aware of AI technologies used for quality control and defect detection during construction	1.39	0.53	NA
8	I am aware of AI-supported tools for decision-making in procurement and contract management.	2.48	0.64	SA
9	I am aware of AI applications in facility management and maintenance planning.	2.22	0.48	SA
10	I am aware of AI tools for generating project progress reports and performance analytics	2.17	0.50	SA
11	I am aware of AI-driven chatbots and virtual assistants for communication with stakeholders.	2.19	0.58	SA
12	I am aware of AI tools used for real-time tracking of materials and logistics	1.37	0.44	NA
Grand Mean/SD		2.28	0.58	Slightly Aware

Keys: N = Number of Respondents; SD = Standard Deviation; HA = High Aware, MA = Moderately Aware, SA = Slightly Aware; NA = Not Aware

The analysis in Table 1 shows the mean and standard deviation of responses of the respondents on 12 items posed to determine the level of awareness of AI tools for building project management among architects and builders in FCT Abuja. A grand mean of 2.22 was obtained, indicating that the respondents jointly agreed that the level of awareness of AI tools is generally slight. The mean values of the items ranged between 1.37 - 3.08, which fall within the categories of “Not Aware,” “Slightly Aware,” and “Moderately Aware.” This implies that while respondents demonstrated moderate awareness of AI applications such as BIM, project scheduling, cost estimation, and construction site safety management, they showed low awareness of advanced applications such as predictive analytics, real-time logistics tracking, and defect detection. The standard deviation of the items ranged from 0.44 - 0.79, which are less than 1.96. This shows that the respondents were relatively close to one another in their responses, suggesting a high level of agreement and consistency in their views about their awareness of AI tools for building project management.

Research Question 2: What is the extent of adoption of AI tools for building project management among architects and builders in FCT Abuja?

The data for answering research question two is presented in Table 2.

Table 2: Mean and Standard Deviation of Respondents on the Extent of Adoption of AI Tools for Building Project Management

S/N	Items	Mean ($\bar{x}$) (N = 312)	SD	Remark
1	I adopt AI-enabled BIM in the design and coordination of project	3.51	0.50	HE
2	I use AI tools for project scheduling and optimization of time management	1.40	0.60	LE
3	I adopt AI applications for cost estimation and budgetary control in building projects	2.47	0.68	ME
4	I apply AI-driven predictive analytics for risk management in construction projects	1.32	0.59	LE
5	I adopt AI-based tools for construction site monitoring and safety management.	1.45	0.65	LE
6	I utilize AI-powered tools for effective allocation and optimization of project resources	1.30	0.76	LE
7	I use AI applications for defect detection and quality control during construction	1.40	0.70	LE
8	I adopt AI-supported decision-making tools in procurement and contract management	1.47	0.63	LE
9	I use AI applications in facility management and long-term maintenance planning	1.42	0.72	LE
10	I apply AI tools for generating project progress reports and performance analytics.	2.40	0.49	ME
11	I adopt AI-driven chatbots or virtual assistants to enhance stakeholder communication	1.29	0.57	LE
12	I use AI for real-time monitoring of logistics and materials tracking	1.27	0.70	LE
Grand Mean/SD		1.73	0.63	Low Extent

Keys: N = Number of Respondents; SD = Standard Deviation; HE = High Extent; ME = Moderate Extent; LE = **Low Extent**

The analysis in Table 2 shows the mean and standard deviation of responses of the respondents on 12 items posed to determine the extent of adoption of AI tools for building project management among architects and builders in FCT Abuja. A grand mean of 1.73 was obtained, indicating that the respondents jointly agreed that the extent of adoption of AI tools is generally low. The mean values of the items ranged between 1.27 - 3.51, which fall within the categories of Low Extent, Moderate Extent, and High Extent. This implies that although respondents demonstrated high adoption of AI-enabled BIM, and moderate adoption of AI tools for cost estimation and project reporting, the majority of other AI applications such as predictive analytics, project scheduling, safety monitoring, resource optimization, quality control, logistics tracking, and stakeholder communication recorded low levels of adoption. The standard deviation of the items ranged from 0.49 - 0.76, which are less than 1.96. This shows that the respondents were relatively close to one

another in their responses, suggesting a high level of agreement and consistency in their views about the extent of adoption of AI tools for building project management.

Discussion of Findings

The findings of research question one revealed that architects and builders in FCT Abuja are slightly aware of AI tools for building project management. This implies that construction professionals in the sampled area have only limited knowledge of the potential applications of AI in managing building projects. Specifically, the respondents demonstrated awareness of AI tools in areas such as BIM, cost estimation, project scheduling, and report generation. However, their awareness of advanced applications such as predictive analytics for risk management, AI-driven logistics tracking, defect detection, and quality control was generally low. This slight level of awareness suggests that while some professionals are familiar with basic or commonly discussed AI applications, a significant knowledge gap exists regarding the broader and more sophisticated uses of AI that can transform project management. It also indicates that, within the context of the FCT Abuja construction industry, architects and builders are only beginning to encounter technological innovations and may not yet be fully exposed to the full range of AI tools available for project delivery.

The finding aligns with previous studies on AI adoption in construction management. Cheche *et al.* (2024) reported that Nigerian construction professionals exhibited minimal awareness of advanced AI technologies due to limited exposure, inadequate sensitization, and insufficient training opportunities. Similarly, Akwaowo *et al.* (2024) observed that although BIM is increasingly recognized in the Nigerian built environment, awareness of AI-driven risk management, real-time monitoring, and logistics tools remains very low. On the global scale, however, studies such as Kerzner (2017) and Russell and Norvig (2021) indicate growing awareness and recognition of AI tools among construction professionals, in technologically advanced countries. The finding implies that the major barriers to awareness are not professional resistance but rather inadequate exposure, lack of structured training, and limited institutional support.

The findings of research question two revealed that the extent of adoption of AI tools for building project management among architects and builders in FCT Abuja is low. This implies that despite some degree of awareness, construction professionals in the area have not substantially incorporated AI into their project management practices. Specifically, adoption was evident in basic applications such as Building Information Modeling (BIM) and project reporting, but the use of advanced AI-driven tools for predictive analytics, logistics tracking, defect detection, and real-time monitoring was found to be very minimal. This low level of adoption suggests that while architects and builders may recognize the existence of AI tools, they face significant challenges in translating awareness into actual usage. It further indicates that within the FCT Abuja construction sector, barriers such as high implementation costs, inadequate training, lack of organizational support, and infrastructural limitations hinder the integration of AI into everyday project management practices.

The finding is consistent with previous studies in the Nigerian construction industry. Afolabi *et al.* (2021) observed that construction professionals often lag in adopting innovative digital tools due to insufficient exposure and institutional constraints. Similarly, Akwaowo *et al.* (2024) noted that

while BIM is slowly gaining ground, broader AI applications in cost control, quality assurance, and risk management remain largely underutilized in Nigeria. By contrast, international studies such as Abioye *et al.* (2021) and Kerzner (2017) reported higher levels of AI adoption in advanced economies, where enabling policies, infrastructure, and training opportunities are more widely available. In the present study, the low extent of adoption among architects and builders in FCT Abuja implies that despite emerging awareness, the sector is not yet prepared to fully harness the benefits of AI for improved project delivery.

Conclusion

The study revealed that architects and builders in FCT Abuja have only a slight awareness and a low extent of adoption of AI tools for building project management. This indicates that, although professionals recognize some potential applications of AI, its practical use in project delivery remains very limited. The findings suggest that deliberate efforts in training, institutional support, and infrastructure development are needed to enhance awareness and promote the adoption of AI in the construction industry for improved efficiency and competitiveness.

Recommendations

The following recommendations were made based on the findings of the study:

3. Professional development programmes, workshops, and seminars should be organized for architects and builders in FCT Abuja to increase their awareness and understanding of AI tools
4. Construction firms, professional bodies and government agencies should provide the necessary infrastructure, technical support, and incentives to encourage the adoption of AI technologies.

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APPRAISAL OF COMPETENCY AND UTILIZATION OF GENERATIVE ARTIFICIAL INTELLIGENCE IN ACADEMIC RESEARCH WRITING AMONG POSTGRADUATE GEOGRAPHY STUDENTS IN KANO STATE, NIGERIA

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Abstract

The integration of Generative Artificial Intelligence (GenAI) tools such as Scite, Elicit, Consensus into academic writing is rapidly transforming research processes across disciplines. This study appraises the competency, utilization and adherence to ethical practices in using GenAI in academic research writing among postgraduate Geography students in Federal and State Universities within Kano State, Nigeria. The study was guided by three objectives and three corresponding research questions and null hypotheses. Using descriptive survey, data were collected by means of online survey through Generative Artificial Intelligence's Competency, Utilisation and Ethical Practices Scale (GenAI-CUES) from 110 participants. The instrument was validated and internal consistency established by using split-half and an index of 0.78 was obtained through Cronbach Alpha. The data collected was analysed using frequency, percentage, expected and observed median and one sample Wilcoxon signed-rank test at 0.05 level of significance. It was revealed that the postgraduate Geography students are moderately using GenAI in academic research writing and their overall competency level and adherence to ethical practices are significantly minimal. In view of these, it was recommended that the Universities should integrate application of GenAI tools in advanced research method courses and organize hands-on training sessions to strengthen students' skills and adherence to ethical considerations in order to ensure academic integrity, responsible authorship and the avoidance of plagiarism or misuse.

Keywords: Generative Artificial Intelligence (GenAI), Geography Education, Academic Research Writing.

Introduction

In recent years, generative artificial intelligence (GenAI) tools such as large language models (Deepseek, Scispace, Concensus, ChatGPT, Google Gemini, Anthropic Claude, Meta LLaMA and many more) and automated writing assistants (Grammarly, Quillbot, Jasper AI, Writefull, Wordtune) have become increasingly prominent in academic research writing. These tools demonstrate considerable significance in enhancing scholarly productivity by facilitating literature reviews, finding research gap, improving writing and grammar, supporting data analysis and strengthening the formulation of well-structured arguments. However, the use of GenAI in research depends largely on three interrelated dimensions; users' competency (skills and literacy), the extent of utilization across various stages of research writing and adherence to ethical considerations that ensure integrity and credibility in academic work.

Competency in the utilisation of GenAI encompasses the knowledge, skills and abilities that enable users to make use of these tools effectively and responsibly. It involves awareness of available tools, skills in prompt writing, the ability to evaluate outputs critically for errors, bias and the integration of human judgment to ensure originality and accuracy. Scholarly interest in GenAI competency has grown in recent years, with studies increasingly examining postgraduate students' engagement with these tools. Evidence suggests that postgraduate students are progressively adopting GenAI in academic practices, with findings pointing from moderate (Chan & Hu, 2023; Aldulaijan & Almalky, 2025; Segooa, Modiba & Motjoloane, 2025) to high competency levels (Rahman et al., 2024; Asante & Frempong, 2025). Similarly, studies across regions indicate moderate to high knowledge and willingness to use GenAI for academic writing and research processes (Suglo, Mejira, Bayor, Nyemewero & Godfred, 2024; Razak, Abdullah, Ahmad, Bakar & Misaridin, 2024; Asante & Frempong, 2025). These studies highlight that students are not only aware of the existence of GenAI but are also able to deploy it in tasks such as information synthesis, research support and academic writing. Effective and proper utilisation of these tools depends squarely on the user's level of capability and ability to adhere to ethical considerations.

Utilization of GenAI in academic research is concern with how someone actively applies generative artificial intelligence tools in academic research writing. This include the specific stages of the academic research writing process where these tools are employed, the frequency of use, and the range of tasks they support. Empirical evidence indicates that students commonly engage GenAI at multiple points throughout the research process which include; idea generation, literature exploration, drafting, editing and refining written outputs. Segbenya, Bervell, Frimpong-Manso, Otoo, Andzie and Achina (2023) report that most postgraduate students rely on GenAI for tasks such as academic writing, language polishing, literature searches and brainstorming.

Applications of GenAI in research often enhance efficiency, support academic creativity, enhance competence and improve the clarity and coherence of research outputs. According to Oliinyk, Bulavina, Romanenko, Tatarnikova and Smirnov (2024), the use of GenAI tools contributes to the development of substantive knowledge, research design capabilities, procedural proficiency and communication skills. These enhancements suggest that when used strategically, GenAI can complement traditional academic skills and foster deeper engagement with complex research process. However, the growing reliance on GenAI technologies is not without risks. Zhai, Wibowo and Li (2024) cautioned that excessive dependence on these tools may undermine essential scholarly competencies such as critical thinking, creativity, and independent problem-solving. Moreover, they highlighted potential ethical challenges, including heightened risks of plagiarism, the dissemination of misinformation and violations of academic integrity standards. These concerns underscore the importance of balanced and critical engagement with GenAI tools where human judgment, verification, and ethical awareness remain central to the research process.

Ethical practices or consideration in the use of GenAI for research entails responsible and righteous application of AI tools in academic work in such a way it will ensure transparency, accuracy, fairness and accountability. It involves disclosing the use of AI, safeguarding data privacy, avoiding plagiarism, critically evaluating outputs for bias or errors and upholding intellectual integrity without undermining originality, authorship and research quality (Limongi, 2024; Sharma & Ghosh, 2025). Although ethical guidelines for AI in research have been widely articulated, studies indicate a persistent gap between principles and practice. Postgraduate students are rapidly

adopting GenAI tools in academic activities. However, many lack the requisite knowledge and skills to engage with these tools responsibly, thereby raising concerns about possible ethical violations. Empirical evidence shows that students often demonstrate moderate levels of awareness and commitment to ethical standards and their practical adherence is limited due to unclear institutional policies, inadequate training and lack of explicit guidance (Sariyasa & Monika, 2023; Hegazy et al., 2024). In light of these challenges, institutions are being urged to develop robust policies and curricula that promote the responsible integration of GenAI into postgraduate research. English, Nash and Mackenzie (2025) emphasize the importance of embedding AI literacy and ethics into higher education programs to equip students with both technical competence and ethical sensitivity.

At the broader academic level, universities and publishers are increasingly adopting regulatory measures to ensure ethical use of AI. Policies now commonly mandate the disclosure of AI involvement in research processes and publications, thereby promoting accountability and safeguarding academic integrity (Cornell Research & Innovation, 2024). These developments suggest a growing recognition of the need to balance the opportunities offered by GenAI with clear ethical boundaries that preserve the credibility of research.

Despite these emerging insights on the GenAI application in academic research writing, significant gaps remain in understanding postgraduate students' competency and utilization of GenAI in research writing as well as level of adherence to ethical issues in certain disciplinary and geographical contexts. In particular, little is known about how postgraduate Geography students in Nigeria and more specifically in Kano State, Nigeria utilize GenAI for academic research writing. These gaps underscore the need for focus investigations to determine the extent of students' competencies, utilization and adherence to responsible GenAI practices within this context. Geography as a discipline requires integration of diverse data sources including spatial analysis, GIS, field data and qualitative/quantitative synthesis which may shape both the competency required and the ways GenAI tools can be utilized. Assessing the levels of competency, degree of utilization and ethical adherence in this context is therefore important for several reasons. It can help universities design training and support programs to enhance students' AI literacy, it can expose ethical risks or misunderstandings which can affect research quality, It can also inform institutional policies on authorship norms, plagiarism detection and responsible GenAI integration.

This study is anchored on the Technology Acceptance Model (TAM) developed by Davis (1989), which explains users' acceptance and utilization of technology based on two major constructs; *perceived usefulness* and *perceived ease of use*. According to Davis, the extent to which an individual perceives a technology as beneficial for enhancing performance (perceived usefulness) and finds it free of effort to use (perceived ease of use) largely determines their intention to adopt and effectively utilize such technology.

In the context of this study, TAM provides a suitable framework for examining postgraduate Geography students' interaction with GenAI tools in academic research writing. Students' competency in using these tools can be linked to their perceived ease of use, while utilization of these tools reflects perceived usefulness. Furthermore, adherence to ethical practices can be interpreted as a moderating factor influencing the acceptance and responsible application of GenAI

tools. Thus, TAM helps to explain not only why students adopt GenAI tools but also the degree of competency and ethical awareness/adherence demonstrated in academic research writing.

Objectives of the Study

The main aim of the study is to appraise postgraduate Geography students' level of competency, utilization and adherence to ethical practices when using generative artificial intelligence in academic research writing in Kano State, Nigeria. However, the study was pinned on the following specific objectives.

1. To assess the level of competency of postgraduate Geography students in the use of generative AI tools for academic research writing.
2. To examine the extent to which postgraduate Geography students utilize generative AI tools in academic research writing.
3. To evaluate postgraduate Geography students' adherence to ethical practices when using generative AI for academic research writing

Research Questions

Based on the objectives of the study, the following research questions were developed to guide the study.

1. What is the level of competency of postgraduate Geography students in the utilisation of generative AI tools for academic research writing?
2. What is the extent of postgraduate Geography students' utilization of generative AI tools in academic research writing?
3. What is the postgraduate Geography students' practices regarding the **ethical use of generative AI** in academic research writing?

Null Hypotheses

Similarly, in accordance with the objectives of the study, the following hypotheses were formulated and tested at 0.05 level of significance.

H₀₁: Postgraduate Geography students in Kano State do not differ significantly in their level of competency in utilization of generative AI for academic research writing from the benchmark median score.

H₀₂: Postgraduate Geography students in Kano State do not differ significantly in their level of utilization of generative AI for academic research writing from the benchmark median score.

H₀₃: Postgraduate Geography students in Kano State do not differ significantly in their adherence to ethical practices when using generative AI for academic research writing from the benchmark median score

Methodology

This study employed a descriptive research design, as it focuses on investigating the levels of competency, utilization, and adherence to ethical practices involved in using Generative AI in academic research writing among postgraduate students. The aim is not to manipulate variables or establish cause-and-effect relationships. The population comprised of 170 postgraduate Geography students in Federal and State Universities in Kano State, out of which 110 participated in the study through online survey. Since the number was manageable, no sampling was conducted.

However, due to attrition 60 students did not respond to the instrument. Data were gathered using the **Generative Artificial Intelligence's Competency, Utilisation and Ethical Practices Scale (GenAI-CUES)**, which covered the constructs of competency and utilization with a baseline score of 20 to 100 points each, and ethical practices with a baseline score of 10 to 50 points in three separate sections respectively. The instrument was validated through expert review, and its internal consistency was established using the split-half method, resulting in a Cronbach Alpha coefficient of 0.78, which was deemed reliable.

Descriptive statistics involving frequency, percentage, and median were used to answer the research questions. The median was chosen because it provides a robust measure of central tendency for ordinal or non-normally distributed data. The hypotheses were tested through non-parametric inferential analysis using **one-sample Wilcoxon signed-rank test** at 0.05 level of significance. The participants' responses on competency and utilization were compared against the benchmark median score of 60, whereas for adherence to ethical principles the benchmark median score of 30 was used. This test was appropriate given the non-parametric nature of the data and its suitability for testing medians against hypothesized or benchmark values.

Data Analysis and Results

Research Question One: What is the level of competency of postgraduate Geography students in the utilisation of generative AI tools for academic research writing?

Table 1: Level of Competency of Postgraduate Geography Students in the Use of Generative AI Tools for Academic Research Writing.

Score Range	Competency Level (Indicator)	Description of Competency	Frequency & Percentage
20 - 29	Not Competent At all	Cannot use GenAI at all	22(20%)
30 - 49	Minimally Competent	Requires a lot of help to use GenAI effectively	45(41%)
50 - 69	Moderately Competent	Require little guidance to use GenAI effectively	22(20%)
70 - 89	Highly Competent	Can use GenAI independently	15(14%)
90 - 100	Extremely Competent	Can teach others how to use GenAI effectively	6(5%)
Total			110(100%)

The results in Table 1 show that among the postgraduate Geography students, majority fall within the lower levels of competency in the use of Generative AI for research. Out of 110 students, the largest group representing 41% (45 students) are minimally competent and thus requiring a lot of help to use GenAI effectively. Another 20% (22 students) are not competent at all, meaning they cannot use GenAI in their academic work. Similarly, 20% (22 students) are moderately competent and require little guidance to use GenAI effectively. Only 14% (15 students) are highly competent and can use GenAI independently. The smallest group with 5% (6 students) are extremely competent and could not only use GenAI effective in research but also can teach others.

Overall, these findings suggest that majority of the postgraduate Geography students, about 61% remain at low to minimal competency levels, while only 19% are in the higher categories of competency. Besides, 20% fall within the moderate level, showing potential but still require some guidance. This distribution indicates a significant competency gap with most students struggling to use GenAI effectively in academic research.

Null Hypothesis One: Postgraduate Geography students in Kano State do not differ significantly in their level of competency in utilization of generative AI for academic research writing from the benchmark median score.

Table 2: One Sample Wilcoxon Signed-Rank Test's Result on Postgraduate Students' Competency in Using GenAI for Research Writing

Variable	N	T	Z	Benchmark Median	Observed Median	p	r	Decision
Competency	110	1,428.500	-4.844	60.00	41.00	<.001	- 0.46	Ho Rejected

Table 2 presents the results of a one-sample Wilcoxon signed-rank test, which showed that $T = 1,428.500$, $Z = -4.84$, observed $Mdn = 41.00$, $p < .001$, and $r = -.46$. Given that the p-value ($< .001$) was less than the level of significance ($\alpha = .05$), the null hypothesis was rejected in favour of the alternative hypothesis. This indicates that the observed median competency score ($Mdn = 41.00$) was significantly lower than the benchmark median score ($Mdn = 60$). The results suggest that postgraduate Geography students generally demonstrated significantly low competency in the use of generative AI for academic research writing, with a medium-to-large effect size ($r = -.46$).

Research Question Two: What is the extent of postgraduate Geography students' utilization of generative AI tools in academic research writing?

Table 3: Extent of Utilisation of Generative AI in Research Writing by Postgraduate Geography Students

Score Range	Usage Level (Indicator)	Description of Usage	Frequency & Percentage
20 - 29	Not at all Use	Never use GenAI tools in research	20(18%)
30 - 49	Rarely Use	Rarely use GenAI tools in research, mostly rely on other alternative means	20(18%)
50 - 69	Moderately Use	Occasionally use GenAI tools for research	40(37%)
70 - 89	Frequently Use	Regularly use GenAI tools for research and consider them a common part of academic work.	20(18%)
90 - 100	Always Used	Consistently use GenAI tools for research and rely on them every time.	10(9%)
Total			110(100%)

The results in Table 3 showed that postgraduate Geography students demonstrate varying levels of usage of Generative AI in research, with the majority exhibiting a moderate level of use. The largest group, representing 37% (40 students) occasionally use GenAI tools in research. This indicates that GenAI is beginning to play a role in academic practice, though it is not yet fully

integrated. A considerable proportion of the students, amounting to 36% (40 students), fall within the categories of Not at all Use (18%) and Rarely Use (18%). These students either do not use GenAI at all or rarely rely on it, preferring to depend on alternative methods. This reflects a significant segment that may be hesitant, less skilled, or unexposed to the potential of GenAI in research activities. On the other hand, 27% (30 students) reported a high level of usage, with 18% using GenAI regularly in research and 9% consistently relying on the tools for every task. This smaller group represents early adopters who view GenAI as an integral component of academic work.

Overall, the findings reveal that GenAI usage among postgraduate Geography students is still at a transitional stage. While more than one-third has embraced moderate usage, only about one-quarter use GenAI frequently or always. Meanwhile, a sizeable portion of the students demonstrate minimal or no usage at all.

Null Hypothesis Two: Postgraduate Geography students in Kano State do not differ significantly in their level of utilization of generative AI for academic research writing from the benchmark median score.

Table 4: One Sample Wilcoxon Signed-Rank Test's Results on Postgraduate Students' Utilisation of GenAI for Research

Variable	N	T	Z	Benchmark Median	Observed Median	p	r	Decision
Utilisation	110	3,035.500	.455	60.00	63.00	.649	.04	Ho Accepted

Table 4 presents the results of a one-sample Wilcoxon signed-rank test, $T = 3,035.500$, $Z = 4.55$, observed $Mdn = 63.00$, $p = .649$ and $r = .04$. Since the p-value (.649) was greater than the level of significance ($\alpha = .05$), the null hypothesis was retained. This indicates that the observed median utilisation score ($Mdn = 63.00$) did not differ significantly from the benchmark median score ($Mdn = 60$). The findings suggest that postgraduate Geography students' utilization of generative AI for academic research writing was comparable to the expected threshold, with a negligible effect size ($r = .04$).

Research Question Three: What is the postgraduate Geography students' practices regarding the ethical use of generative AI in academic research writing?

Table 5: Postgraduate Geography Students' Practices Regarding the Ethical Use of Generative AI in Academic Research Writing

Score Range	Usage Level (Indicator)	Description of Usage	Frequency & Percentage
10 - 14	Never	Does not use ethical principles when using GenAI for research.	48(44%)
15 - 24	Rarely	Rarely acknowledges ethical issues but does not consistently apply them.	30(27%)
25 - 34	Sometimes	Occasionally apply some ethical principles when using GenAI for research.	18(16%)
35 - 44	Often	Regularly incorporates ethical considerations into most research activities and consider them a common part of academic work.	10(9%)
45 -50	Always	Consistently upholds the highest ethical standards in all research activities	4(4%)
Total			110(100%)

Results in Table 3 revealed that the application of ethical practices among postgraduate Geography students in the use of Generative AI for research is generally low. A significant proportion of the postgraduate students, representing 44% (48) reported that they do not apply ethical principles at all in using GenAI for research. This indicates widespread neglect of ethical standards. Furthermore, 27% (30) rarely acknowledge ethical issues and do not consistently apply them, which suggest limited awareness and weak commitment to ethical considerations. 16% (18) of the postgraduate students occasionally apply some ethical principles but this remains irregular and unreliable. Only 9% (10) of the respondents reported that they often incorporate ethical considerations into the use of GenAI for research activities, making it a common part of their academic work, while just 4% (4) consistently uphold the highest ethical standards in academic practices.

Therefore, the results show that the majority of the postgraduate students, accounting for 71% (78) either never or rarely apply ethical principles in research involving the use of Generative AI. In contrast, only a very small fraction, 13% (14) integrate ethical considerations regularly or consistently.

Null Hypothesis Three: Postgraduate Geography students in Kano State do not differ significantly in their adherence to ethical practices when using generative AI for academic research writing from the benchmark median score

Table 6: One Sample Wilcoxon Sign Rank Test's Result on Postgraduate Students' Practices Regarding the Ethical Use of Generative AI in Academic Research Writing.

Variable	N	T	Z	Benchmark Median	Observed Median	p	r	Decision
Utilisation	110	599.500	-7.189	30.00	15.50	<.001	-0.69	Ho Accepted

Table 4 presents the results of a one-sample Wilcoxon signed-rank test, $T = 599.500$, $Z = -7.189$, observed $Mdn = 15.50$, $p < .001$ and $r = -0.69$. Since the p -value ($< .001$) was less than the level of significance ($\alpha = .05$), the null hypothesis was rejected in favour of the alternative hypothesis. This indicates that the observed median score ($Mdn = 15.50$) was significantly lower than the benchmark median score ($Mdn = 30.00$) for adherence to ethical practices. The findings suggest that postgraduate Geography students exhibited a significantly low level of adherence to ethical practices in the use of generative AI for academic research writing, with a large effect size ($r = -0.69$).

Summary of Major Findings

1. The majority of postgraduate Geography students generally demonstrated significantly low to minimal competency in the use of generative AI for academic research writing.
2. Most of postgraduate Geography students exhibited significant moderate utilization of generative AI for academic research writing.
3. Most postgraduate Geography students were found to have a significantly low adherence to ethical practices in the use of generative AI for academic research writing.

Discussion of Findings:

The study established that the majority of postgraduate Geography students generally demonstrated significantly low to minimal competency in the use of generative AI for academic research writing. While many postgraduate students express interest in and awareness of generative AI tools, their actual proficiency remains weak. To buttress this, a large proportion of students fell into the low to minimal competency level, suggesting that they may lack the training, hands-on experience or scaffolding needed to move beyond superficial engagement. This pattern resonates with prior researches. Suglo et al. (2024) found that although postgraduates had moderate to high knowledge and willingness to use generative AI, their actual competency and confidence in applying these tools for research purposes were not robust and prompting. Similarly, Aldulaijan and Almalky (2025), Chan and Hu (2023), and Segooa, Modiba and Motjoloane (2025) each documented instances of shallow or low competency in the use of AI tools.

The study also revealed that most of postgraduate Geography students exhibited significant moderate utilization of generative AI for academic research writing. This finding is in line with the findings of many researches across higher education, including Geography and related disciplines. For instance Chan and Hu (2023) indicated that many students reported using AI tools to save time, receive feedback and enhance digital competence, reflecting moderate but growing integration into their academic routines. Similarly, English, Nash and Mackenzie (2025), and Aldulaijan and Almalky (2025) reported a moderate level of usage among postgraduate students. The last finding expressed that most postgraduate Geography students were found to have a significantly low adherence to ethical practices in the use of generative AI for academic research writing. This finding is in congruent with some existing researches. It was highlighted that many postgraduate students, while increasingly using generative AI for academic research writing, often exhibit low levels of adherence to ethical standards such as transparency, proper attribution and academic integrity. For instance in a study involving graduate students indicated that many used AI as a collaborative tool without always maintaining clear boundaries regarding authorship and originality (Sabbaghan and Eaton, 2025). Moreover, study conducted by Bozkurt (2024) and Chanpradit (2025) revealed that students often rely on AI-generated content without sufficient

critical evaluation or personalization, raising concerns about plagiarism and the erosion of scholarly ethics.

Besides, the literature frequently raises concerns that students fail to follow ethical guidelines when using GenAI. Issues such as ghost authorship (not disclosing AI assistance), uncritical acceptance of AI outputs and unattributed reuse of generated text are common red flags. These practices highlight a weak level of ethical awareness and practice among students and suggest the need for interventions such as training, workshops or policy enforcement to promote responsible and ethical use of Generative AI in academic research.

Conclusion

The findings indicate that most postgraduate Geography students demonstrate a significant limited competency in the application of generative AI for academic research writing. Nonetheless, their level of utilization of these tools is generally moderate, while their adherence to ethical practices remains evidently low. This interplay of limited proficiency, moderate engagement and insufficient ethical compliance underscores a significant gap in both technical capacity and responsible use.

Recommendations

Based on the findings of the study the following recommendations were made.

1. The Universities should integrate application of generative AI tools in advanced research method courses and organized hands-on training sessions to strengthen students' competency in applying these tools for academic research writing. This is order to ensure the students acquire both technical skills and confidence in effective use of GenAI for research.
2. The Universities should integrate structured and guided opportunities for the responsible utilization of generative AI, enabling students to progress from transitional use toward more advanced, effective, and purposeful application in academic research.
3. The Universities should develop and enforce clear ethical frameworks for the responsible use of generative AI, so as to ensure academic integrity, responsible authorship and the avoidance of plagiarism or misuse.

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HARNESSING ARTIFICIAL INTELLIGENCE AND GAMIFICATION THROUGH AN O-LEVEL CHEMISTRY QUIZ AI GAME FOR ENHANCE ACHIEVEMENT AND PROBLEM-SOLVING SKILLS AMONG SECONDARY SCHOOL STUDENTS

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Abstract

In an era where educational technology advances rapidly, the fusion of artificial intelligence (AI) and gamification presents a compelling frontier in science education. This opinion paper explores the potential of an O-Level Chemistry Quiz AI Game as a vehicle for cultivating deeper learning, boosting student achievement, and fostering problem-solving skills among secondary school learners. Drawing on recent literature spanning AI in education, gamified learning, and chemistry pedagogy, the discussion situates this hybrid innovation within both theoretical and pragmatic frameworks. The argument posits that the convergence of AI's adaptivity and gamification's motivational affordances offers a unique terrain for personalised, engaging, and scaffolded chemistry learning experiences. The paper also examines challenges—such as teacher readiness, infrastructure gaps, and equity issues—and offers recommendations for design, implementation, and further research. Ultimately, the perspective put forth is that the O-Level Chemistry Quiz AI Game is not merely a novelty but a strategic intervention capable of transforming how learners engage with chemistry at the O-Level.

Keywords: artificial intelligence, gamification, secondary school chemistry, problem-solving, quiz game, adaptive learning

Introduction

As global education shifts increasingly into the digital era, educators and researchers alike are confronting a crucial question: how can we harness technology not just for novelty, but as a meaningful catalyst for deeper learning? In chemistry education, where abstract concepts and complex problem-solving are paramount, the stakes are particularly high. Many students struggle not merely due to lack of content knowledge but because they lack effective strategies and motivation to tackle novel problems.

This paper puts forward a focused proposition: that an O-Level Chemistry Quiz AI Game — a gamified, AI-driven quiz environment tailored to O-Level chemistry curricula — can significantly enhance student achievement and problem-solving competence. Rather than offering full empirical results, this is a perspective piece that marshals existing scholarship to support the plausibility, promise, and caveats of this approach.

The remainder of the paper unfolds across four interconnected strands. First, the author review how AI and gamification have been applied in education, particularly in science and chemistry contexts. Second, the author articulate how the O-Level Chemistry Quiz AI Game might function, drawing from design principles in the literature. Third, the author engage with empirical and

theoretical critiques, weaving in the references you provided to examine potential pitfalls and enablers. Finally, the author draw out pedagogical implications and recommendations for practitioners and researchers.

The Role of AI and Gamification in Chemistry Education

AI in Education: Personalisation, Adaptivity, and Analytics

Artificial intelligence has moved from promising concept to tangible educational tool. AI can tailor content to individual learners, detect misconceptions, scaffold progressively, and continuously collect data for fine-grained feedback (Ghasem, 2025; Sun et al., 2025). In chemical and STEM disciplines in particular, AI can help students navigate complex conceptual spaces—for instance, modelling reaction mechanisms or guiding error diagnosis (Qureshi et al., 2024; Chiu, 2021).

Yet, the adoption in chemical education is still emergent. Chiu (2021) offered a systematic review of technology in chemistry pedagogy and noted that while digital tools abound, truly intelligent systems remain rare. AI's promise often exceeds its current deployment in classrooms, especially in lower-resourced settings.

Gamification: Engagement, Motivation, and Learning Gains

Gamification overlays game mechanics (points, leaderboards, badges, immediate feedback) onto educational content to boost motivation and engagement. As Kassenkhan, Moldagulova, and Serbin (2025) argue, when thoughtfully designed, gamification can foster higher-order thinking by framing tasks as challenges and promoting competition or collaboration. In education more broadly, gamification has been shown to increase persistence, reduce anxiety, and promote enjoyment (Al-Rousan *et al.*, 2025).

Within science education, incorporating gamified quizzes, simulations, or challenge tasks has begun to attract attention. However, the synergy of gamification with intelligent systems (i.e. AI) is less explored, especially in chemistry.

The Convergence: AI-Enhanced Gamification

Combining AI and gamification offers a potent potential synergy: AI can dynamically adjust the difficulty, detect when a student is stalling, and provide tailored scaffolds, while gamified elements maintain motivation and structure. Polat (2025) examined science teachers' adoption of gamified intelligent tutoring systems and argued through a dual theoretical lens (innovation diffusion + self-determination theory) that teacher beliefs and self-efficacy are critical to uptake. Similarly, Al-Rousan et al. (2025) developed and validated a scale measuring engagement and motivation in AI-enhanced gamification, showing that network analytics can reveal how different engagement components relate to learning outcomes.

This convergence is also reflected in engineering education: Azevedo, Dever, and Wiedbusch (2025) reported on multimodal AI-based game learning in engineering courses, emphasising how adaptation and personalisation enhance student interaction. Their findings offer useful analogies for chemistry education: the more responsive the system, the more students feel understood and supported.

The O-Level Chemistry Quiz AI Game: Conceptual Design

To bring this perspective alive, the author present a conceptual sketch of what the O-Level Chemistry Quiz AI Game might look like.

Core Features & Mechanics

1. Curriculum-Aligned Question Bank

The game would draw from the O-Level chemistry syllabus (e.g., atomic structure, stoichiometry, acids and bases). Questions are categorised by topic, difficulty level, and cognitive demand (e.g. recall, interpretation, multi-step problem-solving).

2. Adaptive Difficulty & Scaffolded Feedback

Using AI algorithms, each learner's responses are analysed in real time. For a correct answer, the next question might nudge toward greater complexity; a wrong answer triggers scaffolded hints, mini-lessons, or guided steps. This aligns with AI's promise of personalisation (Sun *et al.*, 2025; Ghasem, 2025).

3. Gamified Incentives

Learners earn points, badges, and leaderboards. They might “level up” through topics, unlock bonus challenges (e.g. speed rounds, “boss battles” on hard topics), and have streak rewards for consecutive correct responses. Kassenkhan *et al.* (2025) emphasise that gamification's capacity for challenge and reward fosters critical thinking when structured properly.

4. Analytics Dashboard & Teacher Interface

Teachers can monitor class progress, common misconceptions, and difficulty zones. Through visual analytics, they can intervene with mini-lectures or targeted support—aligning with the “learning gaps” perspective (Embang *et al.*, 2025).

5. Collaborative or Competitive Modes

Students may compete or collaborate—say, by forming quiz teams or challenging peers. This social layer amplifies motivation and accountability (Al-Rousan *et al.*, 2025).

6. Periodic Assessments & Reflection

The system could schedule cumulative mini-tests and push learners to reflect (e.g. “Which questions gave you trouble and why?”), thereby fostering metacognition and deeper problem-solving.

Expected Benefits & Supporting Evidence

1. Improved Achievement & Depth of Understanding

Because the system adapts to each learner, it allows weaker students to receive more scaffolding, and stronger students to be challenged further. Qureshi *et al.* (2024) emphasised that AI, when used with effective pedagogical strategies, can elevate understanding in organic and environmental chemistry – a principle equally applicable to O-Level chemistry.

2. Enhanced Problem-Solving Skills

The interplay of scaffolded steps, timed challenges, and layered question complexity encourages students not just to recall facts but to reason, model, and strategise. Kassenkhan

et al. (2025) maintain that gamified structures can push learners into deeper thinking when complexity is calibrated.

3. **Greater Engagement and Motivation**

Al-Rousan *et al.* (2025) demonstrated that engagement and motivation in AI-gamified systems correlate with performance; their validated scale showed that when students feel autonomy, competence, and relatedness (in line with self-determination theory), their persistence increases. Likewise, Alenezi (2023) reported that teachers perceive AI-driven gamification to positively influence motivation and learning outcomes.

4. **Real-time Feedback & Error Correction**

Through intelligent intervention, students can immediately receive diagnostic feedback, reducing misconceptions from hardening. This real-time loop is often missing in traditional quiz-based approaches. Chiu's (2021) review underscored that one of the limitations of digital tools in chemistry is lack of responsive scaffolding something AI aims to remedy.

5. **Insights for Teachers & Curriculum Adjustments**

The analytics dashboard provides aggregate data on difficulty zones and misconceptions, enabling teachers to fine-tune instruction. Embang *et al.* (2025) explored developing AI-based scales to identify learning gaps; similar analytics can detect topics where many students struggle (e.g. limiting reagents or redox), enabling targeted reteaching.

Potential Challenges, Critiques, and Mitigations

1. **Teacher Readiness and Beliefs**

Polat (2025) highlighted that teachers' adoption of gamified intelligent tutoring systems hinges on their beliefs about efficacy and innovation. If teachers perceive the game as a threat to their authority or burdensome to oversee, uptake may falter. Professional development, co-design, and demonstration of efficacy are essential.

2. **Infrastructure Constraints and Equity**

In many contexts, especially in developing regions, access to devices, stable electricity, and internet connectivity can be erratic. Owolarafe *et al.* (2024) studied awareness and usability of AI/gamification tools among senior biology learners in Ilorin and flagged infrastructural and familiarity constraints as major barriers. The O-Level Chemistry Quiz AI Game must thus be optimised for offline or low-bandwidth use and compatible across a range of devices.

3. **Risk of Overjustification / Extrinsic Motivation**

When students become too focused on points or competition, they may lose intrinsic interest in chemistry. Kassenkhan *et al.* (2025) caution that gamification must not overemphasise rewards at the expense of meaning. Design must balance fun with substance.

4. **Algorithm Bias and Misdiagnosis**

AI systems might make incorrect assumptions about student understanding or misclassify errors. If scaffolds are inappropriate or unhelpful, they may frustrate learners. Continuous refinement, human oversight, and a mechanism for user-initiated override are crucial. This is consistent with the caution in Sun *et al.* (2025) about the limits of AI in education.

Sustainability and Maintenance

Developing, updating, and curating a robust question bank, refining AI models, and maintaining software can be resource-intensive. Partnerships between educational institutions, tech developers, and government bodies may be necessary. Makinde and Oyeniyi (2024) emphasised that emerging technology in chemistry must align with sustainable development goals, implying that long-term support is key.

Pedagogical and Practical Implications

For Curriculum Planners & Policymakers

- **Integrate Flexibly**
The AI-gamified quiz should be seen not as a replacement but as a complement to conventional instruction. It can support in-class drills, revision sessions, or homework. Embedding it into official adoption or supplementary schemes increases legitimacy.
- **Equity Considerations**
Policymakers must ensure underprivileged schools have access to the requisite devices, connectivity, and technical support. Subsidies, infrastructure grants, and device-sharing models can help.
- **Standards and Quality Assurance**
National education authorities should establish guidelines and evaluation benchmarks for AI-gamified systems to ensure alignment with syllabus standards and pedagogical quality.

For Teachers

- **Professional Development & Co-Design**
Teachers should be trained not just in using the system but in understanding the AI logic, interpreting analytics dashboards, and integrating game feedback into classroom dialogue. Co-designing parts of the content (e.g. custom quizzes) can enhance teacher buy-in.
- **Blended Instructional Strategies**
Use analytics to identify weak topics, then deploy small-group instruction or targeted mini-lessons. Encourage students to reflect on quiz performance, discuss strategies, and compare approaches.
- **Encourage Metacognitive Reflection**
Prompt students after each session: “Which question challenged you most? Why?” This helps them internalise strategy use and fosters self-regulated learning, resonating with findings from Rizki & Kusumah (2025) in mathematics contexts.

For Designers and Developers

- **Adaptive & Transparent Algorithms**
The AI should prioritise explainability — students should understand *why* an alternate question appears, or feedback is given. This transparency helps build trust.
- **Responsive to Learner Behavior**
The system should detect when a student is stuck, frustrated, or guessing, and pivot (e.g. offer scaffolds or break tasks into smaller steps). Kassenkhan *et al.* (2025) emphasised that well-tuned scaffolding is central to fostering critical thinking.

- **Rich Question Bank & Pedagogical Variety**
Incorporate multiple formats (e.g. multiple-choice, constructed-response, drag-and-drop diagrams, symbolic balancing) to cater to diverse thinking modes. Qureshi *et al.* (2024) remind us that innovation in chemistry education requires mixing representations (symbolic, graphic, contextual).
- **Iterative Improvement via Analytics**
Use the usage data to refine question difficulty, identify misconceptions, and adjust scaffold strategies. Designers can draw inspiration from how Azevedo *et al.* (2025) used multimodal analytics to enhance game-based learning in engineering disciplines.

For Researchers

- **Pilot and Mixed-Method Studies**
Conduct pilot studies in real classrooms to test usability, engagement, and learning gains. Mixed-method approaches (quantitative + qualitative) can unearth not only *whether* the system works, but *how* and *for whom*.
- **Comparative Studies**
Compare the AI-gamified quiz with traditional quizzes, non-gamified intelligent tutoring systems, or conventional lectures to isolate the added value of gamification × AI.
- **Longitudinal Research**
Investigate whether gains in achievement and problem-solving persist over time, and whether student attitudes toward chemistry shift. Also track whether participation prompts uptake into advanced science courses.
- **Contextual Variation & Scalability**
Study how context (urban vs rural, high-resource vs low-resource schools) mediates efficacy. Investigate strategies for scale, maintenance, and cost-effectiveness.

Conclusion

This opinion paper has argued that an O-Level Chemistry Quiz AI Game — combining the adaptivity and feedback powers of AI with the motivational scaffolding of gamification — holds strong potential as a transformative tool in chemistry education. The literature suggests several converging advantages: personalised learning pathways, increased motivation, deeper engagement with content, and access to fine-grained analytics to guide instruction.

However, realizing this promise demands careful, context-aware design and strong support systems. Teachers must be actively involved and empowered; infrastructure gaps must be addressed equitably; scaffold design and algorithmic transparency must be prioritised; and continuous evaluation must guide improvement.

Recommendations

Here are key recommendations:

1. Engage teachers as co-designers so they feel ownership and understand the AI logic.
2. Ensure offline or low-bandwidth functionality to accommodate underserved contexts.

3. Balance gamified incentives with meaningful content, avoiding overemphasis on rewards alone.
4. Build and maintain a robust question bank including varying cognitive levels and representations.
5. Deploy pilot studies and iterative refinement, tracking both learning outcomes and student experience.

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TEACHERS' READINESS, COMPETENCE AND ATTITUDE AS CORRELATES OF ICT USAGE AMONG SECONDARY SCHOOL MATHEMATICS TEACHERS

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Abstract

In an era where digital technology shapes every dimension of education, the readiness, competence and attitude of mathematics teachers towards the use of Information and Communication Technology (ICT) have become pivotal. This paper argues that ICT integration in mathematics teaching is not merely a technical process but a pedagogical transformation that hinges on teachers' preparedness, digital competence and disposition towards innovation. Drawing from recent empirical studies conducted across Africa, Asia and Europe, this opinion paper highlights that while many mathematics teachers recognise ICT's instructional potential, disparities in digital readiness, skill acquisition and attitude continue to affect implementation. It contends that effective ICT usage requires not just infrastructure but a shift in teachers' mindsets and pedagogical practices. The discussion synthesises evidence from contemporary research, reflecting on policy challenges and institutional gaps that hinder digital adoption. The author concludes with recommendations for professional development, policy alignment and institutional support systems that can empower mathematics teachers to integrate technology meaningfully and sustainably.

Keywords: Attitude toward ICT Integration, Digital Competence, ICT Readiness, Mathematics Education, Perceived Self-Efficacy, Teacher Competence and Technology Integration

Introduction

Mathematics education has long been perceived as abstract and challenging, yet digital technologies have opened unprecedented opportunities to make it more interactive, visual and learner-centred. Information and Communication Technology (ICT) enhances conceptual understanding through dynamic simulations, visual representations and collaborative tools that foster active learning. Despite these advantages, the full potential of ICT in mathematics instruction depends significantly on teachers' readiness, competence and attitudes (Arhin, Boateng, Akosah, and Gyimah, 2024).

Globally, educators are transitioning from traditional teacher-led instruction to technology-enriched pedagogies. However, this transition is uneven. In several developing contexts, teachers face barriers such as inadequate digital literacy, limited access to resources and resistance to pedagogical change (Demissie, Labiso, and Thuo, 2022; Shittu, Gambari, Gimba, and Ahmed, 2018). The readiness of teachers defined by their willingness, motivation and preparedness to use ICT is thus a crucial determinant of successful technology integration. Similarly, their competence both technical and pedagogical determines the depth and creativity of ICT application in mathematics classrooms (Agyei et al, 2022).

Attitude also plays a defining role. Teachers with positive perceptions towards ICT are more likely to adopt innovative instructional approaches and sustain technology use (Ardıç, 2021; Hero, 2020). This paper offers an informed perspective on how these three dimensions interact to influence ICT integration among secondary school mathematics teachers.

Teachers' Readiness and Digital Preparedness

Teachers' readiness forms the foundation of ICT adoption. It encompasses not only access to digital tools but also confidence, awareness *and* willingness to employ them in instructional settings. A recent study by Arhin *et al.* (2024) revealed that mathematics teachers in Ghana demonstrated favourable perceptions toward ICT integration but varied in their actual readiness levels. Those with prior exposure to digital tools displayed greater confidence and creativity in designing lessons using technology.

Similarly, Omar and Mohmad (2023) found that in Malaysia, readiness was influenced by prior pedagogical training and ICT skills, suggesting that digital competence training is indispensable for fostering readiness. Rodríguez-Muñiz *et al.* (2021) observed during the COVID-19 pandemic that emergency remote teaching exposed the unpreparedness of many mathematics teachers to deliver instruction online, highlighting that readiness is as much about mindset as it is about skill. In the African context, Shittu *et al.* (2018) modelled technology preparedness as a predictor of self-efficacy and intention to use ICT, revealing that teachers' psychological readiness significantly affects their adoption behaviour. These findings collectively suggest that readiness is a multi-dimensional construct influenced by access, training, motivation *and* institutional support. Without systemic efforts to improve these factors, ICT integration risks becoming superficial rather than transformative.

Teachers' Competence in ICT Integration

Competence goes beyond knowing how to operate digital devices it involves the pedagogical ability to use technology meaningfully for teaching mathematics. Agyei *et al.* (2022) highlighted that in-service mathematics teachers who possessed higher self-efficacy in technology use demonstrated better integration during lesson delivery. This aligns with Birgin *et al.* (2020) findings that Turkish mathematics teachers perceived themselves as moderately proficient, yet many lacked the pedagogical knowledge required to use ICT effectively in problem-solving contexts.

Machaba and Bedada (2022) also reported similar challenges among Ethiopian university lecturers who trained mathematics teachers, citing a mismatch between available technology and lecturers' instructional competence. The Technological Pedagogical Content Knowledge (TPACK) framework has been widely acknowledged as a useful model for developing ICT competence. Marbán and Sintema (2021) showed that pre-service mathematics teachers with stronger TPACK demonstrated more positive attitudes towards ICT integration, underlining the role of teacher education in shaping digital competence.

The study by Demissie *et al.* (2022) reinforced this by revealing that digital competencies are a function of continuous exposure and support rather than a one-time training event. Thus, competence in ICT integration must be cultivated through continuous professional development, peer mentoring *and* reflective practice.

Attitude Toward ICT and Its Effect on Teaching Practices

Teachers' attitudes often determine whether ICT tools are adopted enthusiastically or reluctantly. A positive attitude can catalyse innovation, while resistance can impede progress. Galaraga and Reynato Jr (2022) found that competence and attitude significantly predicted teachers' readiness for digitised instruction. In contrast, negative attitudes were frequently associated with anxiety, fear of failure, or lack of institutional incentives.

Alieto *et al.* (2024) demonstrated that across various disciplines, teachers with strong technological competence and favourable attitudes were more confident in digital classrooms. In mathematics education specifically, Ardiç (2021) and Çenberci and Yavuz (2018) both identified a strong correlation between positive attitudes toward instructional technology and creative lesson delivery. These teachers tended to design more engaging materials and encouraged students to explore mathematical concepts interactively.

Moreover, Ismail *et al.* (2019) observed that teachers' perceptions and readiness for implementing critical thinking practices in mathematics were influenced by their openness to digital methods. A later study by Ismail *et al.* (2022) reinforced that teachers with favourable dispositions were more likely to practise digital-assisted approaches that promote analytical reasoning.

Attitude, therefore, mediates the relationship between readiness and competence. Even when teachers are equipped with skills, a negative outlook can limit ICT utilisation. Cultivating a growth mindset, therefore, remains central to ICT integration success.

Challenges and Policy Gaps

Despite the clear benefits of ICT integration, numerous barriers persist. Infrastructure deficits such as unreliable electricity, limited internet access *and* inadequate hardware remain major obstacles in many developing regions (Demissie *et al.*, 2022; Shittu *et al.*, 2018). Teachers also cite time constraints, heavy workloads *and* insufficient institutional support as deterrents (Hero, 2020; Arhin *et al.*, 2024).

Policy frameworks often emphasise ICT adoption without adequately addressing capacity building and follow-up evaluation. For instance, Machaba and Bedada (2022) observed that during the pandemic, Ethiopian institutions rushed to digitalise instruction but overlooked the long-term sustainability of such interventions. Similarly, Li (2022) reported that in mainland China, EFL teachers faced high expectations to integrate ICT yet lacked consistent support structures, resulting in uneven literacy levels.

Funding limitations further compound the issue, as professional development programmes are often one-off rather than continuous (Agyei *et al.*, 2022). Additionally, curriculum rigidities restrict teachers' flexibility to integrate innovative digital methods in mathematics lessons. Policymakers need to move beyond infrastructure provision to build holistic ecosystems that encompass training, incentives *and* curriculum reform.

Table 1: Summary of Empirical Studies on Teachers' Readiness, Competence and Attitude toward ICT Usage in Mathematics Education

S/N	Author(s) and Year	Location / Area of Study	Research Methodology / Sample	Results / Findings
1	Çenberci and Yavuz (2018)	Turkey	Quantitative study involving mathematics teacher candidates enrolled in an instructional technology and material design course.	Found a significant positive correlation between creative thinking tendencies and attitudes toward instructional technologies. Teacher candidates who were more creative tended to have more favourable attitudes toward ICT integration.
2	Shittu et al. (2018)	Nigeria	Quantitative study using structural equation modelling with pre-service mathematics teachers.	Revealed that technology preparedness predicted self-efficacy, perceived usefulness and intention to use ICT. Suggested that readiness training improves ICT adoption intention among mathematics teachers.
3	Ismail et al. (2019)	Malaysia	Descriptive survey of mathematics teachers implementing critical thinking skills (CTS) in teaching.	Showed that teachers' perception and readiness toward ICT-supported CTS implementation were moderate; training and administrative support were critical factors influencing readiness.
4	Birgin et al. (2020)	Turkey	Survey of secondary school mathematics teachers on ICT proficiency perceptions.	Found that teachers rated their ICT proficiency as moderate, with significant differences based on teaching experience and access to training. Highlighted the need for professional development in digital pedagogy.
5	Hero (2020)	Philippines	Quantitative descriptive study with in-service teachers.	Indicated that teachers' preparedness and acceptance of ICT significantly influenced their integration practices. Positive attitudes correlated with frequent and innovative technology use in classrooms.
6	Ardıç (2021)	Turkey	Mixed-method study with secondary school mathematics teachers.	Demonstrated generally positive opinions and attitudes toward technology. Teachers acknowledged ICT's benefits but cited limited resources and training as barriers to deeper integration.
7	Rodríguez-Muñiz et al. (2021)	Spain	Case study on secondary mathematics teachers during COVID-19	Revealed that most teachers were unprepared for digital teaching despite high motivation. Highlighted

S/N	Author(s) and Year	Location / Area of Study	Research Methodology / Sample	Results / Findings
			emergency remote teaching.	gaps in institutional support and training for online instruction.
8	Marbán and Sintema (2021)	Spain and Zambia	Quantitative survey of pre-service mathematics teachers.	Found a strong relationship between TPACK competence and positive attitudes toward ICT integration. Emphasised the role of teacher education programmes in building ICT pedagogical knowledge.
9	Agyei et al. (2022)	Ghana	Quantitative study with in-service mathematics teachers.	Identified high levels of technology awareness but varying degrees of practical competence. Self-efficacy strongly influenced the use of ICT for instructional delivery.
10	Galaraga and Reynato Jr (2022)	Philippines	Quantitative survey of secondary school teachers.	Established that competence and attitude significantly predicted readiness for digitised instruction. Emphasised continuous professional development to sustain readiness.
11	Ismail et al. (2022)	Malaysia	Mixed-method research with mathematics teachers across schools.	Found that teachers perceived themselves moderately ready to integrate critical thinking and ICT-based practices. Recommended enhanced ICT training for mathematics educators.
12	Demissie et al. (2022)	Ethiopia (Wolaita Zone)	Descriptive survey of secondary school teachers.	Reported limited digital competence among teachers due to infrastructural challenges and inadequate support. Highlighted the digital divide between rural and urban schools.
13	Machaba and Bedada (2022)	Ethiopia	Quantitative study among university lecturers in teacher education.	Found that lecturers were only moderately prepared to use technology for mathematics instruction during COVID-19. Recommended policy-driven training and infrastructure enhancement.
14	Li (2022)	Mainland China	Quantitative study of EFL teachers during COVID-19.	Showed mixed levels of ICT literacy and acceptance. Teachers' readiness correlated strongly with prior digital experience and access to institutional support.
15	Omar and Mohmad (2023)	Malaysia	Quantitative research among secondary school teachers.	Identified pedagogy, ICT skills and teaching readiness as predictors of digital competence. Concluded that ICT readiness is context-dependent and linked to skill proficiency.

S/N	Author(s) and Year	Location / Area of Study	Research Methodology / Sample	Results / Findings
16	Arhin, Boateng, Akosah, and Gyimah (2024)	Ghana	Quantitative study among high school mathematics teachers.	Revealed positive perceptions toward ICT integration but moderate readiness levels. Emphasised the importance of professional development and resource access.
17	Alieto, Abequibel-Encarnacion, Estigoy, Balasa, Eijansantos, and Torres-Toukourmidis (2024)	Philippines	Quantitative cross-disciplinary survey across teaching subjects.	Found that teachers' attitude, competence <i>and</i> access significantly influenced ICT use in digital classrooms. Mathematics teachers displayed relatively higher competence and confidence in ICT integration.

Author's Perspective

As an educator and researcher in mathematics education, I contend that ICT integration must be perceived not as a technological reform but as a pedagogical reimagination. Mathematics teaching demands abstract reasoning and conceptual modelling; ICT can serve as a bridge between abstract theory and concrete understanding when teachers are adequately prepared and confident.

Drawing from the reviewed studies, it is clear that readiness, competence *and* attitude are interdependent. Readiness establishes the psychological and logistical foundation, competence empowers teachers with the necessary skills *and* attitude sustains innovation through motivation and commitment. However, the current professional development landscape in many contexts remains fragmented and reactive. Programmes are frequently donor-driven and lack contextual adaptation, leading to superficial adoption that fails to transform teaching practice.

The author advocate for a sustainable professional development model one that integrates continuous learning communities, peer mentoring *and* reflective practice. Institutions should foster environments where teachers are encouraged to experiment with ICT without fear of failure. Furthermore, educational authorities should adopt *bottom-up* approaches that consider teachers' local realities when designing digital policies.

ICT should not replace the teacher but rather amplify their pedagogical reach. The mathematics teacher of the 21st century must therefore be both a content expert and a digital facilitator who nurtures students' problem-solving and critical thinking through meaningful technology use.

Conclusion

mathematics education stands at the intersection of tradition and technology. Teachers are the fulcrum of this transformation; their readiness, competence *and* attitude collectively determine whether ICT serves as a tool for empowerment or a missed opportunity. A holistic, context-driven *and* human-centred approach remains essential to ensure that technology in mathematics teaching enhances, rather than complicates, the learning process.

Recommendations

For ICT integration in mathematics education to be effective and enduring, systemic action is essential. Based on evidence and reflective analysis, the following recommendations are proposed:

1. **Continuous Professional Development:** Governments and educational institutions should prioritise sustained professional development programmes focusing on pedagogical integration of ICT, not merely tool operation.
2. **Institutional Support and Mentorship:** Schools should establish peer mentoring systems where digitally competent teachers guide others, fostering a collaborative learning culture
3. **Policy Coherence:** Ministries of education must align ICT policies with curriculum goals and teacher capacity frameworks to ensure realistic implementation.
4. **Attitude Transformation:** Teacher education programmes should incorporate modules that address digital mindset, creativity *and* innovation in teaching mathematics.
5. **Infrastructure and Access Equity:** Equal opportunities for digital access must be ensured across urban and rural schools to avoid widening the digital divide.
6. **Research-Driven Practice:** Further longitudinal studies should explore how teachers' readiness, competence *and* attitude evolve with ongoing exposure to ICT in mathematics classrooms.

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ASSESSING SCIENCE TEACHERS' STEM INTEGRATION PRACTICES IN SECONDARY SCHOOL SCIENCE INSTRUCTION: EVIDENCE FROM MINNA EDUCATION ZONE, NIGER STATE.

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Abstract

This study investigated science teachers' Science, Technology, Engineering, and Mathematics (STEM) integration practices in secondary school science instruction in the Minna Education Zone of Niger State, Nigeria. A descriptive survey design was adopted, involving a sample of 291 science teachers selected through multistage sampling from 11 secondary schools across three Local Government Areas. Data were collected using a validated questionnaire titled Instructional Practices of Science Teachers for Promoting STEM Education in the Twenty-First Century, with a reliability coefficient of 0.81. Data analysis was conducted using descriptive statistics such as mean and standard deviation. Findings revealed that the extent of science teachers' implementation of STEM-integrated instructional practices was low ($M = 2.10$, $SD = 0.84$), indicating that teachers rarely apply engineering design, open-ended problems, or technology integration in science classrooms. Similarly, instructional strategies that promote STEM learning, such as project-based, inquiry-based, and design-based approaches, were rarely employed ($M = 2.24$, $SD = 0.97$), with lecture methods remaining dominant. Moreover, assessment strategies used to evaluate students' learning in integrated STEM education were limited, with teachers relying mainly on traditional methods such as interviews and reflective writing ($M = 2.14$, $SD = 0.88$). The study concludes that despite growing emphasis on STEM education, science teachers in the Minna Education Zone have not fully adopted integrative pedagogies and authentic assessments. It recommends continuous professional development programs focusing on STEM integration, provision of adequate instructional resources, to enhance the implementation of effective STEM-based instruction and assessment in secondary schools.

Keywords: STEM education, instructional practices, instructional strategies, assessment practices, secondary school science teachers

Introduction

The rapid pace of technological advancement, globalization, and evolving societal needs has made Science, Technology, Engineering, and Mathematics (STEM) education pivotal for preparing students to succeed in the 21st century. STEM integration in instruction enables learners to engage in authentic problem-solving, engineering design, real-world contexts, and technology, thereby fostering critical thinking, creativity, and innovation (Halawa & Hsu, 2024; Crotty, Cox-Petersen, & Lee, 2018). In many countries, including Nigeria, governments, education authorities, and scholars have underscored the importance of STEM to economic development, national competitiveness, and sustainable growth (Aina, 2022; Ukeje & Chiebonam, 2025). However, realising the potential of STEM integration requires not only policy support but also effective teaching practices, appropriate instructional strategies, and valid assessment methods.

In Nigeria, prior studies have pointed out challenges such as inadequate infrastructure, lack of teacher training, insufficient instructional materials, and unclear curriculum guidelines as

impediments to effective STEM instruction (Gimba, Hassan, Yaki, & Chado, 2018; . Despite these recognitions, there is limited empirical data at the local level (for example, in Minna Education Zone, Niger State) on how science teachers implement STEM integration in practice, including the instructional strategies they use, the frequency and fidelity with which they implement them, and how they assess student learning in such settings.

STEM integration involves the deliberate blending of two or more disciplines: Science, Technology, Engineering, and Mathematics to reflect the interconnected nature of real-world challenges, emphasizing inquiry, problem-solving, and design thinking. Effective integration requires teachers to move beyond subject silos to create learning experiences that mirror authentic contexts (Crotty et al., 2018; Fang & Fan, 2022). However, research indicates that many teachers still struggle to establish explicit connections among the STEM domains, often emphasizing science concepts with limited incorporation of technology tools or engineering design processes. This challenge underscores the importance of appropriate instructional and assessment practices that can operationalize STEM integration in classroom settings.

Instructional strategies form the pedagogical bridge that enables meaningful STEM integration. Strategies such as project-based learning, inquiry-based learning, problem-based learning, and engineering design challenges have been shown to enhance learners' engagement, collaboration, and higher-order thinking (Halawa & Hsu, 2024; Mohd Yahya Jusoh *et al.*, 2022). These methods encourage students to apply knowledge across multiple STEM fields, thereby fostering creativity and problem-solving aligned with twenty-first-century learning goals. Yet, in developing contexts such as Nigeria, teachers' adoption of such strategies remains inconsistent, often constrained by inadequate training, limited instructional resources, and heavy workloads (Olabiyi et al., 2021; Gimba *et al.*, 2018). Without robust instructional support, STEM integration efforts risk remaining theoretical rather than practical.

Assessment practices represent the evaluative dimension of STEM integration, ensuring that learning outcomes reflect students' ability to think critically, design solutions, and apply interdisciplinary knowledge. Authentic assessments, such as performance tasks, design rubrics, and formative feedback, are essential for capturing complex learning processes in STEM-based instruction (Halawa & Hsu, 2024). However, studies report that many teachers still rely on traditional tests focusing on content recall, largely due to difficulties in designing valid tools for project-based or integrated learning contexts (Crotty *et al.*, 2018). Consequently, effective STEM education depends on the alignment of integration practices, instructional strategies, and assessment approaches. When these three elements are coherently implemented, they reinforce one another. Integrated curricula promote inquiry-based strategies, which in turn require authentic assessments to measure real-world problem-solving competencies.

This study, therefore, assesses the practices of science teachers in secondary schools in Minna Education Zone with respect to STEM integration, focusing on instructional implementation, strategies, and assessment. Findings are expected to provide evidence for improving teacher preparation, instructional support, and policy implementation in STEM education in Niger State and similar contexts.

Statement of the Problem

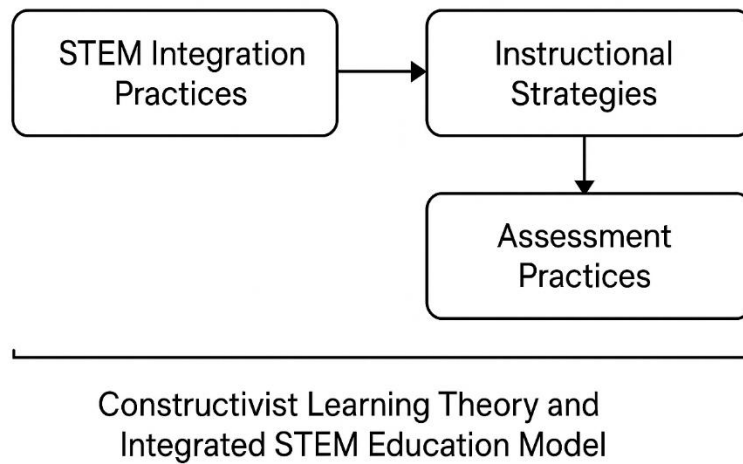
While policy pronouncements and educational reforms in Nigeria emphasise STEM education, there remains a substantial gap between the theoretical expectations of integrated STEM instruction and what actually happens in classrooms. Many science teachers struggle to operationalize STEM instructional practices such as engineering design, open-ended problem solving, real-world contextualization, technology integration, and inquiry questioning. Furthermore, there is scant information about which strategies teachers are using and how they assess STEM-based learning. Without understanding these practices in context, policy efforts and professional development may not adequately address the actual needs, leading to suboptimal student engagement and outcomes. In the Minna Education Zone of Niger State, it is unknown to what extent these instructional and assessment practices are being implemented, what strategies are being employed, and whether these align with 21st century STEM education ideals. This lack of empirical evidence hampers targeted interventions and improvement in science instruction.

Research Questions

1. To what extent do science teachers in secondary schools in Minna Education Zone implement STEM-integrated instructional practices (e.g., engineering design challenges, problem-based learning, technology use, and inquiry questioning)?
2. What instructional strategies do science teachers employ to facilitate integrated STEM learning experiences in secondary science classrooms?
3. What assessment strategies do science teachers use to evaluate students' learning in integrated STEM education?

Conceptual Framework

The conceptual framework illustrates the relationship among the three key constructs of the study: STEM Integration Practices, Instructional Strategies, and Assessment Practices as grounded in the Constructivist Learning Theory and the Integrated STEM Education Model.



In the diagram, STEM Integration Practices form the starting point, representing how teachers combine science, technology, engineering, and mathematics in classroom instruction. These practices directly influence the Instructional Strategies teachers adopt, such as inquiry-based, project-based, and problem-based learning approaches. The effectiveness of these strategies then shapes the Assessment Practices, which evaluate students' ability to apply integrated STEM knowledge through authentic, performance-based tasks.

Research Methodology

This study adopted a descriptive survey design, which enables the researcher to systematically describe a population's characteristics, behaviours, and patterns without manipulating variables. The design was considered appropriate for this investigation because it provides quantitative evidence on teachers' instructional practices for promoting STEM education in the twenty-first century. The population comprised 1,204 science teachers across 160 secondary schools in the Minna Education Zone of Niger State, covering six Local Government Areas—Bosso, Chanchaga, Kagara, Shiroro, Suleja, and Paikoro (Zonal Inspector of Education, Minna, 2021). Using a multistage sampling technique, a total of 291 science teachers were selected from 11 schools in three Local Government Areas (Bosso, Chanchaga, and Suleja). The sample size was determined using the Krejcie and Morgan (1970) table to ensure representativeness while minimizing cost and time.

A structured questionnaire titled *"Instructional Practices of Science Teachers for Promoting Science, Technology, Engineering, and Mathematics Education in the Twenty-First Century"* served as the research instrument. It comprised five sections: (a) demographic information (gender, years of experience, and school location); (b) level of implementation of STEM practices (20 items); (c) instructional strategies used (10 items, rated from Often Used to Never Used); and (d) assessment strategies (12 items). The instrument's face and content validity were established by three experts, one from the School of Environmental Technology, Federal University of Technology, Minna, Niger State, and two from the College of Education, Minna, who evaluated clarity, language, and relevance of items. Reliability was determined using Cronbach's alpha

method on responses from 24 science teachers at Day Secondary School, Minna, yielding a coefficient of 0.81, indicating that the instrument was reliable for data collection.

The researcher visited the selected schools and obtained permission from the school authorities to conduct the study, as well as the informed consent of the respondents. The research instruments were then administered, and the data collected were analyzed using descriptive statistics, including the mean and standard deviation, to address the research questions.

Results

To what extent do science teachers in secondary schools in Minna Education Zone implement STEM-integrated instructional practices? To answer this research question, data were analyzed using mean and standard deviation.

Table 1: Mean and Standard Deviation on the Extent of Science Teachers' Implementation of STEM-Integrated Instructional Practices (N = 291)

S/N	Items	Mean	SD	Decision
1	The learners are always presented with an open-ended problem to guide the lesson.	2.03	0.77	Rarely Implemented
2	Science teaching and learning are linked to a real-world scenario.	2.15	0.92	Rarely Implemented
3	I ensure learning activities in STEM are presented to provide hands-on training to enhance the practical know-how of students.	2.01	0.76	Rarely Implemented
4	Students are asked questions to define the problems to be solved.	1.86	0.78	Rarely Implemented
5	Students are provided with the opportunity to generate ideas to proffer solutions to identified complex problems.	2.03	0.88	Rarely Implemented
6	Students work in small groups to share ideas and communicate with each other.	1.97	0.85	Rarely Implemented
7	Small group discussions and brainstorming are organized for students to work as a team to proffer solutions to identified problems collectively.	2.05	0.76	Rarely Implemented
8	I frequently use the lecture method for science instruction.	3.02	1.0	Often Implemented
9	I include real-life experiences in the teaching of STEM to help in developing critical thinking skills in students.	1.94	0.79	Rarely Implemented
10	I integrate instructional technologies such as mobile learning.	2.2	0.95	Rarely Implemented
11	I engage students in computer-aided instruction to foster meaningful learning of science.	1.83	0.74	Rarely Implemented
—	Average Mean	2.1	0.84	Rarely Implemented

Note. Decision rule: 3.50–4.00 = Always Implemented; 2.50–3.49 = Often Implemented; 1.50–2.49 = Rarely Implemented; 1.00–1.49 = Never Implemented.

The results presented in Table 1 show that the overall mean score for science teachers' implementation of STEM-integrated instructional practices was 2.10 (SD = 0.84), corresponding

to the decision level of Rarely Implemented. This indicates that, on average, science teachers in the Minna Education Zone infrequently adopt STEM-integrated instructional approaches in their classrooms.

A closer inspection of the items reveals that practices such as presenting open-ended problems ($M = 2.03$, $SD = 0.77$), linking science instruction to real-world scenarios ($M = 2.15$, $SD = 0.92$), organizing small group discussions ($M = 2.05$, $SD = 0.76$), and integrating instructional technologies ($M = 2.20$, $SD = 0.95$) were all rarely implemented. Only the use of the lecture method ($M = 3.02$, $SD = 1.00$) was reported as often implemented, indicating a continued reliance on conventional teaching methods rather than inquiry-based or technology-enhanced approaches. These findings suggest a low level of STEM integration in science classrooms across the Minna Education Zone, possibly due to inadequate professional development, limited instructional resources, or insufficient exposure to integrated STEM pedagogy.

What instructional strategies do science teachers employ to facilitate integrated STEM learning experiences in secondary science classrooms? To address this research question, data were analyzed using mean and standard deviation.

Table 2: Mean and Standard Deviation on Instructional Strategies Used by Science Teachers (N = 291)

S/N	Instructional Strategies	Mean	SD	Decision
1	Design-based Learning	2.23	0.94	Rarely Used
2	Project-based	2.36	0.82	Rarely Used
3	Flipped Classroom	2.07	0.84	Rarely Used
4	Problem-Based Learning	2.35	1.11	Rarely Used
5	Peer Instruction	2.29	0.91	Rarely Used
6	Lecture	3.28	0.91	Used
7	Computer-Based Instruction	2.23	1.0	Rarely Used
8	Think-Pair-Share	2.22	0.98	Rarely Used
9	Drill & Practice	2.18	1.07	Rarely Used
10	Class or Small-Group Discussion	2.11	0.84	Rarely Used
11	Experiments	2.06	0.91	Rarely Used
12	Inquiry-Based	1.76	0.82	Rarely Used
—	Average Mean	2.24	0.97	Rarely Used

Note. Decision key: 1.00–1.49 = Not Used; 1.50–2.49 = Rarely Used; 2.50–3.49 = Used; 3.50–4.00 = Often Used.

The results in Table 2 indicate that the overall mean score for instructional strategies employed by science teachers to promote integrated STEM learning was 2.24 ($SD = 0.97$), which falls within the range of *Rarely Used.*

This finding suggests that science teachers in secondary schools within the Minna Education Zone infrequently employ instructional strategies that promote integrated STEM learning experiences. Item-by-item analysis shows that strategies such as design-based learning ($M = 2.23$, $SD = 0.94$), project-based learning ($M = 2.36$, $SD = 0.82$), problem-based learning ($M = 2.35$, $SD = 1.11$),

inquiry-based learning ($M = 1.76$, $SD = 0.82$), and computer-based instruction ($M = 2.23$, $SD = 1.00$) were all rarely used by teachers. The only strategy that appeared to be used was the lecture method ($M = 3.28$, $SD = 0.91$), indicating that most teachers still rely heavily on teacher-centered, traditional instructional methods. This pattern highlights limited adoption of innovative, student-centered pedagogies that are essential for effective STEM integration.

What assessment strategies do science teachers use to evaluate students' learning in integrated STEM education? Mean and Standard Deviation were used to answer research question three, as shown in Table 3

Table 3: Mean and Standard Deviation on instructional assessment used by science teachers (N=291)

S/N	Instructional Assessment	Mean	Std.	Decision
1	Interviews	2.54	0.97	Used
2	Reflective Writing	2.50	0.84	Used
3	Projects	2.41	0.96	Rarely Used
4	Quizzes and Polls	2.26	0.85	Rarely Used
5	Diagnostic assessment	2.24	1.00	Rarely Used
6	Experiments Report	2.17	1.01	Rarely Used
7	Peer Review Exercises	2.07	0.82	Rarely Used
8	Essay-Type Questions	2.04	0.83	Rarely Used
9	Self-Assessments	2.03	0.94	Rarely Used
10	Group presentations	1.97	0.76	Rarely Used
11	Performance and formative assessment	1.93	0.86	Rarely Used
12	Assignments	1.53	0.73	Rarely Used
	Average Mean	2.14	0.88	Rarely Used

Decision key: Not Used = 1.0 – 1.49, Rarely Used = 1.5 - 2.49, Used = 2.5 – 3.49 and Often Used = 3.5 – 4.0

The results in Table 3 reveal that the overall mean score was 2.14 ($SD = 0.88$), indicating that assessment strategies for integrated STEM learning were *rarely used* by science teachers in the Minna Education Zone. This finding suggests that teachers rely more on traditional assessment methods rather than authentic or performance-based assessments that align with STEM integration principles.

Item-wise analysis shows that only interviews ($M = 2.54$, $SD = 0.97$) and reflective writing ($M = 2.50$, $SD = 0.84$) were rated as *used*, while other strategies such as projects ($M = 2.41$, $SD = 0.96$), experiments report ($M = 2.17$, $SD = 1.01$), peer review exercises ($M = 2.07$, $SD = 0.82$), and group presentations ($M = 1.97$, $SD = 0.76$) were *rarely used*. The lowest mean scores were recorded for assignments ($M = 1.53$, $SD = 0.73$) and performance/formative assessments ($M = 1.93$, $SD = 0.86$), indicating limited use of authentic assessment methods. Overall, these results reflect the predominance of teacher-centred evaluation methods and highlight a need for capacity building in effective STEM-aligned assessment practices.

Discussion of Findings

Overall, the results revealed that science teachers rarely implement integrated STEM instructional practices, seldom use innovative instructional strategies, and depend largely on traditional assessment methods. These outcomes reflect a persistent gap between policy intentions and classroom realities in STEM education within the region. STEM-Integrated Instructional Practices The results from Research Question One indicated that STEM-integrated instructional practices such as inquiry questioning, engineering design, and problem-based learning are rarely implemented by science teachers. The overall mean score of 2.10 (SD = 0.84) shows that teachers infrequently engage students in activities that promote critical thinking, collaboration, or hands-on problem solving. Only the lecture method was often used, indicating a strong reliance on conventional, teacher-centered pedagogy. This finding agrees with earlier studies Gimba et al., (2018) that reported similar patterns across Nigerian schools. From the theoretical perspective, these findings are consistent with Constructivist Learning Theory, which posits that learners construct knowledge actively through authentic experiences. The limited adoption of hands-on, inquiry-based activities suggests that many teachers still operate within a transmission-based instructional paradigm, rather than a constructivist, learner-centred model, thereby hindering students' opportunities for experiential learning and knowledge application.

Results from Research Question Two revealed that most teachers rarely use student-centred instructional strategies such as project-based, inquiry-based, and design-based learning, with an overall mean of 2.24 (SD = 0.97). The lecture method was again the most frequently used strategy (M = 3.28, SD = 0.91). This finding aligns with those of Crotty, Cox-Petersen, and Lee (2018) and Mohd Yahya Jusoh et al. (2022), who observed that while STEM education emphasizes active participation, collaboration, and problem-solving, teachers often default to lecture-oriented instruction due to limited training and time constraints.

For Research Question Three, the results showed that assessment strategies aligned with STEM pedagogy were rarely used, with an overall mean of 2.14 (SD = 0.88). Most teachers relied on interviews and reflective writing, while more authentic assessment forms such as performance tasks, peer review, and project evaluations were seldom applied. These findings mirror those of Halawa and Hsu (2024), who emphasized that STEM assessment should evaluate students' capacity for design thinking, collaboration, and innovation rather than rote recall. The prevalent use of traditional tests indicates a disconnection between learning objectives and evaluation approaches, thereby limiting students' ability to demonstrate authentic STEM competencies.

Conclusion

This study concludes that science teachers in secondary schools in the Minna Education Zone exhibit a generally low level of STEM integration in their instructional, strategic, and assessment practices. The findings revealed that while teachers recognize the relevance of STEM, they often revert to conventional lecture-based teaching, rarely incorporating hands-on, inquiry-based, or technology-driven learning experiences.

Recommendations

1. The Ministry of Education and school administrators should organize continuous professional development workshops focused on STEM-integrated pedagogy, emphasizing inquiry-based and project-based approaches.

2. Pre-service and in-service teacher education programs should include practical modules on STEM integration, emphasizing the use of instructional technologies and design thinking.
3. Schools should provide adequate facilities and resources—such as laboratories, ICT tools, and instructional materials—to support hands-on STEM activities.
4. Assessment systems should be restructured to incorporate authentic performance-based evaluation aligned with STEM learning outcomes.

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THE ROLE OF MASTERY LEARNING IN IMPROVING ACADEMIC ACHIEVEMENT AND RETENTION IN ALGEBRA: A REVIEW

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Abstract

Algebra forms the foundation of advanced mathematical reasoning and problem-solving, making it an essential subject in secondary education. However, persistent challenges in academic achievement and retention in Mathematics, particularly in Nigeria, continue to undermine students' performance in national examinations such as WAEC, NECO, and NABTEB. This review explores the role of Mastery Learning as an instructional strategy designed to improve students' achievement and long-term retention in Algebra. Drawing on Bloom's theory of Mastery Learning, the paper highlights key features such as stepwise instruction, formative assessment, corrective feedback, and individualized learning. Empirical evidence from Nigeria and other contexts demonstrates that Mastery Learning promotes higher levels of conceptual understanding, problem-solving ability, and sustained retention compared to conventional teacher-centred approaches. Findings also suggest positive implications for gender equity, learner motivation, and cumulative learning outcomes. Despite these benefits, research gaps remain, particularly in the areas of longitudinal studies, regional disparities, and integration of digital learning tools with mastery-oriented instruction. The paper concludes by recommending the adoption of Mastery Learning principles in classroom practice, teacher education, and curriculum policy as a viable means of enhancing achievement and retention in Algebra and, by extension, secondary school Mathematics.

Keywords: *Mastery Learning, Algebra, Academic Achievement, Retention, Mathematics Education, Nigeria, Secondary School, Bloom's Theory*

Introduction

Mathematics is widely recognized as the cornerstone of scientific and technological advancement, with Algebra occupying a central place in the secondary school curriculum. Algebra is not only a gateway to advanced mathematical concepts but also underpins the development of logical reasoning, abstract thinking, and problem-solving skills required for participation in a knowledge-based economy. Research continues to affirm that proficiency in Algebra strongly predicts students' future success in science, technology, engineering, and mathematics (STEM) disciplines (Akinpelu *et al.*, 2024). Consequently, sustained difficulties in Algebra represent a significant barrier to educational and occupational advancement for many learners.

In the Nigerian context, poor academic performance in Mathematics has remained a recurring concern for educators, policymakers, and examination bodies. Reports from the West African Examinations Council (WAEC), the National Examinations Council (NECO), and the National Business and Technical Examinations Board (NABTEB) consistently highlight low pass rates in Mathematics, with Algebra topics being among the most problematic areas. Studies attribute these challenges to factors such as overcrowded classrooms, limited instructional resources, negative student attitudes, and reliance on teacher-centered methods that do not adequately address learners' diverse needs (Habu *et al.*, 2024). The outcome is that a significant proportion of students graduate

without the requisite competence in Algebra, thereby reducing their readiness for higher-level studies.

Retention of knowledge is another dimension of this challenge. Algebra, being cumulative in nature, requires that students recall and apply previously learned concepts when approaching new material. However, evidence indicates that many Nigerian students exhibit poor retention, struggling to transfer earlier learning into new contexts (Okwuduba & Ofoegbu, 2022). Weak retention contributes to recurring patterns of underachievement, as students who cannot recall foundational concepts are ill-equipped to grasp more complex algebraic ideas. This interplay between low achievement and poor retention underscores the need for alternative instructional approaches that emphasize deep learning and long-term comprehension.

Against this background, instructional strategies that move beyond the limitations of conventional teaching have gained attention. One such strategy is Mastery Learning, a model that organizes instruction so that students must achieve a predetermined level of understanding before progressing to subsequent units. Mastery Learning emphasizes formative assessment, corrective feedback, and individualized pacing, ensuring that no learner is left behind due to time constraints or rigid sequencing. This approach stands in contrast to conventional teacher-centered methods, which typically advance all students at the same pace regardless of individual mastery (Bloom, 1968/2020).

Bloom's Mastery Learning theory, complemented by Carroll's model of school learning, provides a theoretical foundation for this approach. Both frameworks emphasize that given adequate time, feedback, and opportunities for correction, most students can achieve mastery of academic content (Carroll, 1989; Mededmentor, 2023). Recent adaptations of Mastery Learning highlight its potential to enhance not only immediate academic achievement but also retention of knowledge through repeated practice and reinforcement (Akinpelu et al., 2024; Igbokwe, 2023). These theoretical underpinnings suggest that instructional strategy is a crucial determinant of achievement and retention outcomes in Algebra.

Empirical studies in Nigeria and beyond have begun to validate this proposition. Quasi-experimental evidence from secondary schools indicates that students taught using Mastery Learning strategies outperform their peers taught through conventional methods in both achievement and retention tests (Akinpelu et al., 2024; Okwuduba & Ofoegbu, 2022). Moreover, recent findings suggest that Mastery Learning positively influences students' engagement and motivation, which are themselves predictors of higher achievement (Adebola & Fajobi, 2025). By fostering a sense of competence and success, Mastery Learning may also reduce mathematics anxiety, a known barrier to performance in Algebra.

Nonetheless, research gaps remain evident. While short-term intervention studies provide promising results, fewer longitudinal investigations track how mastery-based approaches influence performance and retention across multiple academic years. Furthermore, most Nigerian studies are region-specific, often concentrated in urban areas of the southwest, raising questions about generalizability to other contexts with differing resources and socio-cultural conditions (Igbokwe, 2023). These gaps highlight the need for systematic reviews that synthesize current evidence, assess its implications, and identify directions for future research.

This review therefore aims to examine the role of Mastery Learning in improving academic achievement and retention in Algebra among Nigerian secondary school students. Specifically, it analyses conceptual foundations, synthesizes empirical evidence, compares Mastery Learning with conventional strategies, and evaluates implications for teaching practice and educational policy. By doing so, the study underscores the potential of Mastery Learning to address persistent challenges in Mathematics education and to contribute to more equitable and effective learning outcomes in Algebra.

Conceptual Understanding of Mastery Learning

Mastery Learning is an instructional strategy that assumes virtually all learners are capable of achieving high levels of understanding when provided with sufficient time, appropriate feedback, and individualized support. Initially proposed by Bloom in the late 1960s, the model emphasizes that learning should be organized into sequential steps, with students required to demonstrate mastery of a concept before progressing to subsequent material (Bloom, 2020). The underlying principle is that while learners differ in the time needed to master content, they can reach a common level of achievement if instruction is designed to accommodate their pace.

This theoretical foundation is reinforced by Carroll's model of school learning, which conceptualizes learning as a function of opportunity, perseverance, and quality of instruction (Carroll, 1989). Contemporary interpretations of both Bloom's and Carroll's frameworks highlight the centrality of formative assessment and corrective feedback in bridging gaps in learning. Recent studies affirm that mastery-based approaches create conditions for learners to consolidate knowledge more effectively, thereby enhancing both achievement and retention (Akinpelu et al., 2024; Igbokwe, 2023).

In practical terms, Mastery Learning is characterized by several interrelated components. These include the division of content into smaller, coherent units, the use of formative tests to monitor progress, corrective instruction for learners who fall short of mastery, enrichment activities for students who succeed quickly, and flexible pacing to accommodate differences in learning rates (Mededmentor, 2023). The synergy of these components creates a learner-centered environment where feedback and support are continuous, contrasting sharply with conventional teacher-centered models that rely on rigid timelines and summative assessments.

Recent empirical evidence from Nigerian classrooms demonstrates how these components operate in practice. Akinpelu et al. (2024), for example, employed mastery strategies in teaching geometry by using pre-tests, targeted instruction, and corrective feedback, leading to significantly higher achievement among students compared to those taught with conventional methods. Similarly, Adebola and Fajobi (2025) reported that mastery-oriented classrooms fostered greater cognitive, affective, and behavioral engagement, suggesting that the model supports not only academic achievement but also positive dispositions toward learning.

The conceptual appeal of Mastery Learning also lies in its potential to enhance retention. Since Algebra requires cumulative knowledge, students who receive repeated practice, timely feedback, and remediation are better positioned to recall and apply previously learned material (Okwuduba & Ofoegbu, 2022). This positions Mastery Learning as particularly relevant in Mathematics education, where failure to master foundational skills often undermines subsequent learning.

Moreover, Mastery Learning interacts with variables such as gender, prior achievement, and student engagement. Evidence suggests that while the model benefits learners broadly, those with lower pre-test scores often experience the greatest gains (Akinpelu et al., 2024). In contrast, gender differences have been found to influence affective and behavioral engagement, though not necessarily cognitive outcomes (Adebola & Fajobi, 2025). These findings indicate that Mastery Learning not only supports equity but also offers differentiated pathways for diverse learners.

In summary, the conceptual understanding of Mastery Learning rests on the integration of theoretical insights from Bloom and Carroll with practical strategies such as formative assessment, corrective feedback, and individualized pacing. By aligning instructional design with the goal of universal mastery, the model addresses challenges of both achievement and retention in Algebra. This conceptual framework provides a lens through which the effectiveness of mastery-based approaches can be assessed, offering direction for both empirical inquiry and pedagogical practice in Nigerian secondary schools.

Academic Achievement in Mathematics

Academic achievement in Mathematics refers to the extent to which learners acquire, demonstrate, and apply mathematical knowledge, skills, and problem-solving abilities, typically measured through standardized tests, classroom assessments, and national examinations. Achievement in Mathematics is not only a key indicator of cognitive development but also a determinant of students' readiness for higher education and participation in science, technology, engineering, and mathematics (STEM) fields. In the Nigerian secondary school system, Mathematics achievement carries additional weight as it is a compulsory subject and a prerequisite for admission into most tertiary programs (Habu et al., 2024). Consequently, poor achievement in Mathematics, particularly in Algebra, limits students' academic mobility and constrains their future opportunities.

The relevance of Mathematics achievement is underscored by empirical studies that consistently link high performance in the subject with problem-solving ability, logical reasoning, and adaptability to real-life situations. Algebra, as a central domain of Mathematics, provides the foundation for advanced topics such as calculus, probability, and statistics. Students' ability to achieve mastery in Algebra is thus strongly correlated with their overall performance in Mathematics and related disciplines (Akinpelu *et al.*, 2024). When achievement in Algebra is weak, students are unable to progress meaningfully in higher-level mathematical reasoning, which in turn lowers their performance in both internal and external assessments.

Evidence from Nigerian secondary schools indicates that conventional teacher-centered pedagogies have contributed to persistent underachievement in Mathematics. These approaches typically emphasize rote memorization and summative assessment, offering limited opportunities for feedback and remediation. As a result, many students are unable to grasp foundational concepts, leading to cumulative knowledge gaps (Igbokwe, 2023). The inadequacies of conventional instruction are further reflected in WAEC and NECO reports, where average pass rates in Mathematics remain consistently low, with algebraic concepts identified as areas of weakness for a majority of students (WAEC, 2023).

In contrast, Mastery Learning has emerged as a promising strategy for addressing these challenges. Its emphasis on stepwise instruction, formative assessment, and corrective feedback provides a structure that supports students in achieving mastery of Algebraic concepts before advancing to more complex topics. Recent quasi-experimental studies have shown that students taught through Mastery Learning strategies outperform their counterparts taught through conventional approaches. For instance, Akinpelu *et al.* (2024) reported significant gains in secondary school students' performance in Geometry when Mastery Learning principles were applied, suggesting a similar potential for Algebra instruction.

Beyond immediate performance, Mastery Learning has been shown to promote deeper conceptual understanding rather than surface memorization. By requiring students to demonstrate mastery through formative assessments, the approach ensures that learning outcomes are meaningful and transferable to new contexts. This deeper understanding equips students to solve non-routine problems, a skill increasingly valued in national examinations and global education standards (Adebola & Fajobi, 2025). Thus, achievement under Mastery Learning is not limited to improved test scores but extends to enhanced problem-solving and critical thinking abilities.

Another important dimension of Mathematics achievement under Mastery Learning is equity. Conventional approaches often exacerbate performance gaps between high- and low-achieving students, as instruction moves forward without ensuring that all learners have grasped key concepts. Mastery Learning, however, reduces these disparities by providing additional time and corrective instruction to those who need it. Empirical findings from Nigerian classrooms reveal that students with initially low pre-test scores benefit significantly from mastery-oriented instruction, thereby narrowing achievement gaps and promoting inclusivity (Akinpelu *et al.*, 2024).

Furthermore, research highlights that academic achievement under Mastery Learning is often mediated by student engagement and motivation. Adebola and Fajobi (2025) found that students taught through mastery strategies reported higher cognitive and affective engagement, which contributed to improved academic outcomes. This suggests that Mastery Learning not only directly enhances achievement but also indirectly fosters the psychological conditions necessary for sustained success. Engagement, therefore, serves as a mediating variable linking instructional strategy to achievement outcomes.

In sum, academic achievement in Mathematics, particularly in Algebra, is a critical outcome for secondary school learners in Nigeria and beyond. While conventional teacher-centered approaches have failed to deliver sustained improvement, evidence increasingly supports Mastery Learning as an effective alternative that enhances performance, deepens conceptual understanding, reduces achievement gaps, and fosters student engagement. These findings provide a strong rationale for situating Mastery Learning at the center of pedagogical reforms aimed at improving Mathematics achievement in Nigerian secondary schools.

Retention in Mathematics

Retention in Mathematics refers to the ability of learners to store, recall, and apply previously acquired mathematical knowledge over time. Unlike short-term performance, which reflects immediate understanding, retention emphasizes the long-term preservation of knowledge and

skills. This construct is particularly significant in cumulative subjects such as Algebra, where later concepts build systematically on earlier foundations. Without adequate retention, students struggle to integrate new knowledge with prior learning, leading to disjointed understanding and persistent learning gaps (Oyeleke & Chinedu, 2024). Retention, therefore, is not merely an educational outcome but a prerequisite for progressive mathematical learning.

The significance of retention in Mathematics is further underscored by its impact on examination performance and lifelong learning. National examination bodies in Nigeria, such as WAEC and NECO, consistently report students' inability to recall and apply basic algebraic principles as a major cause of low pass rates (WAEC, 2023). For example, students who fail to retain the rules of algebraic manipulation or factorization find it difficult to solve advanced equations, leading to recurring failure across multiple academic levels. Thus, improving retention is essential to breaking the cycle of poor achievement in secondary school Mathematics.

A critical factor influencing retention is the instructional method employed. Conventional teacher-centered approaches, which emphasize rote memorization and rapid content coverage, often fail to ensure durable learning. Students may temporarily memorize procedures to pass tests but quickly forget them due to the absence of reinforcement and meaningful engagement (Hassan & Jimoh, 2023). By contrast, Mastery Learning provides opportunities for repeated practice, corrective feedback, and reinforcement of concepts, all of which are mechanisms shown to improve long-term memory consolidation.

Empirical research affirms the effectiveness of Mastery Learning in promoting retention. Akinpelu *et al.* (2024) demonstrated that students taught with mastery strategies retained geometric problem-solving skills significantly better than those taught using traditional methods when assessed after a delay. Similarly, Adebola and Fajobi (2025) reported that mastery-oriented Algebra instruction enhanced both immediate achievement and delayed retention, indicating that the strategy facilitates deeper encoding of knowledge into long-term memory. These findings align with Bloom's (1976) original proposition that mastery-oriented instruction promotes not just achievement but also durable learning outcomes.

The mechanisms through which Mastery Learning enhances retention include formative assessment, feedback loops, and corrective instruction. Formative assessment enables teachers to identify misconceptions early, preventing the accumulation of faulty knowledge. Corrective feedback provides students with targeted guidance to refine their understanding, while additional practice reinforces neural pathways associated with mathematical problem-solving. Together, these mechanisms ensure that learning is not only achieved but also retained (Adebola & Fajobi, 2025). This integration of assessment and feedback directly links the concept of mastery to long-term retention.

Beyond cognitive mechanisms, motivational factors also influence retention. When students experience success through mastery-oriented instruction, their confidence and self-efficacy in Mathematics increase, making them more likely to engage in sustained practice (Oyeleke & Chinedu, 2024). Sustained engagement, in turn, reinforces retention. Conversely, repeated failure under conventional approaches reduces motivation, leading to disengagement and poor long-term

outcomes. Hence, retention is indirectly linked to achievement through the mediating role of motivation.

Reports from Nigerian examination bodies support these findings. WAEC (2023) and NABTEB (2022) highlight persistent weaknesses in algebraic topics that require the recall of previously learned procedures, suggesting gaps in retention rather than exposure. These reports imply that improving students' ability to retain foundational concepts could significantly improve national examination outcomes. As such, mastery-based interventions could be instrumental in addressing systemic weaknesses in the Nigerian education system.

In summary, retention in Mathematics is a crucial determinant of students' ability to succeed in cumulative topics such as Algebra. While conventional methods have struggled to foster long-term knowledge preservation, Mastery Learning has proven effective in promoting retention through its emphasis on formative assessment, corrective feedback, repeated practice, and learner motivation. Strengthening retention not only enhances achievement but also ensures the sustainability of learning outcomes, thereby contributing to students' academic progression and overall mathematical literacy.

Empirical Evidence from Nigeria and Beyond

Empirical investigations into Mastery Learning have generated a growing body of evidence on its effectiveness in improving academic achievement and retention in Mathematics across diverse contexts. In Nigeria, where challenges in Mathematics education are persistent, several studies have tested mastery-oriented instructional strategies in secondary schools with notable outcomes. These studies consistently demonstrate that Mastery Learning not only enhances immediate achievement but also promotes long-term retention, reduces gender disparities, and fosters learner motivation. The cumulative evidence suggests that Mastery Learning represents a viable solution to the recurring underachievement in Mathematics within the Nigerian educational system.

Research from Nigerian classrooms has shown that students exposed to Mastery Learning strategies significantly outperform their peers in conventional classrooms. For example, Akinpelu *et al.* (2024) conducted a quasi-experimental study on senior secondary school students in Osogbo and reported that mastery-based instruction led to substantial gains in performance in Geometry. Their findings are consistent with other Nigerian studies in Algebra and Trigonometry, which highlight the strategy's capacity to improve students' conceptual understanding and problem-solving skills (Igbokwe, 2023). These results reinforce Bloom's assertion that all learners can achieve mastery when provided with appropriate instructional support and sufficient time for learning.

In terms of retention, Adebola and Fajobi (2025) demonstrated that Nigerian students taught Algebra through Mastery Learning retained knowledge better when tested after a delay, compared to students instructed via traditional methods. Similarly, Oyeleke and Chinedu (2024) found that mastery-oriented feedback and reinforcement contributed to stronger long-term recall of mathematical concepts. These findings indicate that Mastery Learning facilitates durable knowledge acquisition, which directly addresses the retention challenges repeatedly highlighted in WAEC and NECO examiners' reports.

Studies have also explored the role of gender in mastery-oriented classrooms. Conventional teaching approaches often reproduce achievement gaps between male and female students in Mathematics, with boys typically outperforming girls. However, evidence suggests that Mastery Learning reduces these disparities. Akinpelu *et al.* (2024) found no significant gender difference in achievement outcomes under mastery-oriented instruction, suggesting that the individualized nature of the strategy supports equitable learning opportunities. This aligns with global findings where mastery-based strategies have been credited with narrowing gender gaps in STEM disciplines (Yildirim & Kaplan, 2022).

Another dimension highlighted in Nigerian studies is the motivational effect of Mastery Learning. Adebola and Fajobi (2025) reported that students in mastery-oriented classrooms demonstrated higher levels of interest, engagement, and confidence in Mathematics compared to those taught conventionally. Motivation is a critical variable, as it not only influences immediate achievement but also supports sustained engagement with cumulative subjects such as Algebra. These motivational benefits further explain why Mastery Learning promotes both achievement and retention.

Beyond Nigeria, international evidence supports the efficacy of Mastery Learning across different cultural and educational contexts. In a large-scale study in Turkey, Yildirim and Kaplan (2022) found that mastery-oriented Mathematics instruction significantly improved middle school students' performance and self-efficacy, with effects persisting into subsequent academic years. Similarly, in a South African context, Nkosi (2023) reported that mastery strategies enhanced learners' Algebra performance in rural schools, emphasizing the adaptability of the approach in resource-constrained settings. These findings underscore the global relevance of Mastery Learning while also reinforcing its applicability in Nigeria.

Despite these promising outcomes, gaps in the research remain. Most Nigerian studies on Mastery Learning are quasi-experimental and limited to small samples within specific regions. Longitudinal studies that track the sustained effects of mastery-oriented instruction across multiple academic years are scarce. Moreover, there is limited research on the integration of digital technologies with Mastery Learning in Nigerian schools, despite the increasing role of e-learning platforms in global education (Habu *et al.*, 2024). Addressing these gaps could provide more robust evidence to guide large-scale implementation of Mastery Learning within the Nigerian education system.

In conclusion, empirical evidence from Nigeria and other countries consistently highlights the effectiveness of Mastery Learning in improving Mathematics achievement, retention, gender equity, and motivation. However, future research must address the limitations of small-scale, short-term studies by incorporating longitudinal designs, regional comparisons, and digital innovations. Such efforts will strengthen the evidence base and support the scaling of Mastery Learning as a pedagogical strategy for transforming Mathematics education in Nigeria and beyond.

Implications for Teaching and Policy

The growing body of evidence on the effectiveness of Mastery Learning has significant implications for classroom practice, teacher education, and educational policy in Nigeria and beyond. At the classroom level, Mastery Learning offers a structured framework that allows

teachers to ensure all students achieve clearly defined learning objectives before progressing to more complex content. This implies a shift from conventional teacher-centered instruction to a more learner-focused approach, where formative assessments, corrective feedback, and individualized support are integral to daily practice (Akinpelu et al., 2024). Such a shift requires teachers to reconceptualize their roles, moving from transmitters of knowledge to facilitators of active, mastery-driven learning.

One implication for classroom practice is the need for teachers to adopt stepwise instructional strategies that emphasize prerequisite learning. Algebra, for instance, requires students to build on prior knowledge of arithmetic, symbols, and basic equations before advancing to functions and quadratic expressions. Mastery Learning ensures that foundational knowledge is solidified through iterative feedback and corrective interventions, thereby preventing cumulative learning gaps (Oyeleke & Chinedu, 2024). This approach also promotes differentiated learning, as it accommodates learners who require additional time and support without compromising the pace of advanced learners.

Teacher education and professional development programs are central to the effective implementation of Mastery Learning. Nigerian teachers often receive limited training in formative assessment and diagnostic instruction, which are essential components of the mastery approach. To embed mastery-oriented strategies into everyday practice, teacher training curricula must be revised to include modules on mastery pedagogy, assessment for learning, and individualized instruction (Adebola & Fajobi, 2025). Continuous professional development programs, particularly those supported by technology, can further help teachers refine these practices in real classroom contexts.

Curriculum design is another area that demands attention. Current Nigerian curricula, particularly at the secondary level, tend to emphasize breadth over depth, covering a wide range of topics within limited instructional time. This structure is often at odds with the principles of Mastery Learning, which require flexibility and sufficient time for remediation (Igbokwe, 2023). Policymakers and curriculum planners must therefore consider restructuring syllabi to allow adequate time for formative assessment, corrective teaching, and individualized instruction. Such reforms could significantly improve both achievement and retention in cumulative subjects like Algebra.

At the policy level, integrating Mastery Learning into national education strategies could help address systemic underperformance in Mathematics. Reports from WAEC and NECO have consistently shown poor pass rates in Mathematics, particularly in algebraic concepts, suggesting the need for evidence-based reforms (WAEC, 2023). Policymakers should incorporate Mastery Learning into instructional guidelines, teacher training frameworks, and school evaluation criteria. Doing so would align teaching practices with research evidence and create a standardized approach to improving Mathematics achievement nationwide.

Technology integration further enhances the scalability of Mastery Learning. Digital platforms and learning management systems can provide individualized feedback, track student progress, and offer adaptive learning resources aligned with mastery principles. In contexts where teacher-student ratios are high, such as in many Nigerian schools, technology-enabled mastery instruction

can provide personalized learning opportunities that would otherwise be difficult to achieve (Habu *et al.*, 2024). National education policies should therefore encourage the adoption of blended learning models that combine digital mastery tools with teacher-led instruction.

In addition, Mastery Learning has equity implications for education policy. By reducing performance gaps between high- and low-achieving students, as well as between male and female learners, mastery-oriented instruction supports inclusive education (Yildirim & Kaplan, 2022). Policymakers can leverage these equity benefits to promote educational justice, particularly in underserved rural and urban areas where Mathematics achievement remains persistently low. This aligns with broader national and international goals, such as Nigeria's Education for All framework and the United Nations Sustainable Development Goal 4 on inclusive, equitable, and quality education.

Overall, the implications of Mastery Learning extend from individual classrooms to national policy frameworks. By embedding mastery principles into teaching practice, teacher training, curriculum design, and policy implementation, stakeholders can create a more effective and equitable Mathematics education system. Such systemic reforms have the potential to not only improve Algebra achievement and retention but also to enhance students' preparedness for STEM careers and national development.

Conclusion

This review has examined the role of Mastery Learning in improving academic achievement and retention in Algebra, situating the discussion within the broader context of Mathematics education in Nigeria and beyond. The persistent underachievement of students in national examinations such as WAEC, NECO, and NABTEB underscores the urgency of adopting more effective instructional strategies. Evidence reviewed in this paper demonstrates that Mastery Learning offers a viable solution, as it ensures that students acquire foundational knowledge, receive corrective feedback, and engage in repeated practice before progressing to higher-level content (Akinpelu *et al.*, 2024; Adebola & Fajobi, 2025).

A key finding of this review is that Mastery Learning significantly improves academic achievement in Mathematics. By emphasizing formative assessment, individualized instruction, and corrective teaching, mastery-oriented approaches foster deeper conceptual understanding, enhanced problem-solving ability, and improved examination performance. This stands in contrast to conventional teacher-centered methods, which often result in rote memorization, surface learning, and cumulative knowledge gaps (Igbokwe, 2023). The strategy's effectiveness in promoting both immediate and long-term achievement aligns with Bloom's theoretical postulation that all students can attain high levels of learning given sufficient time and support.

Retention in Mathematics emerged as another critical outcome of Mastery Learning. In cumulative subjects such as Algebra, retention is indispensable for sustained academic progression. Empirical evidence from Nigeria and other contexts reveals that mastery-based instruction promotes durable knowledge acquisition by reinforcing concepts through corrective feedback and iterative practice (Oyeleke & Chinedu, 2024). This not only ensures long-term recall but also enables students to integrate new knowledge with prior learning, thereby preventing disjointed understanding and repeated failure in examinations (WAEC, 2023).

The review also highlighted additional benefits of Mastery Learning, including its capacity to reduce gender disparities and foster learner motivation. Evidence indicates that mastery-oriented instruction supports both high- and low-achieving students by providing differentiated opportunities for learning, thus promoting educational equity (Yildirim & Kaplan, 2022). Furthermore, by enabling students to experience success through formative feedback, Mastery Learning enhances self-efficacy, engagement, and positive attitudes toward Mathematics, which in turn support long-term achievement and retention (Adebola & Fajobi, 2025).

Despite these benefits, research gaps remain. Most studies in Nigeria have been limited to small-scale, quasi-experimental designs that do not capture the long-term effects of Mastery Learning. There is also a lack of research on integrating digital tools with mastery-oriented strategies in Mathematics classrooms, even though global studies suggest that technology can enhance personalization and scalability (Habu et al., 2024). Addressing these gaps through longitudinal, large-scale, and technology-integrated studies would provide more robust evidence to inform policy and practice.

The implications of these findings are far-reaching. For classroom practice, teachers must shift toward learner-centered approaches that prioritize mastery over coverage. For teacher education, professional development programs should incorporate training in formative assessment, corrective instruction, and mastery pedagogy. At the policy level, curriculum planners and education authorities must integrate mastery principles into national instructional guidelines and provide resources for their effective implementation. These reforms will not only improve Algebra outcomes but also enhance Nigeria's overall STEM readiness and human capital development.

In conclusion, Mastery Learning represents a powerful instructional strategy with the potential to transform Mathematics education in Nigeria and similar contexts. By strengthening both achievement and retention, reducing disparities, and fostering motivation, mastery-oriented instruction addresses some of the most pressing challenges in secondary school Mathematics. Future research should focus on longitudinal impacts, regional disparities, and the integration of digital technologies with mastery pedagogy. If effectively implemented, Mastery Learning can serve as a cornerstone of educational reform, equipping students with the mathematical competencies necessary for academic success, career readiness, and national development.

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ARTIFICIAL INTELLIGENCE AS A CATALYST FOR CAREER DEVELOPMENT IN TEACHER EDUCATION: OPPORTUNITIES, CHALLENGES AND ETHICAL CONSIDERATIONS IN UNIVERSITY OF NIGERIA NSUKKA.

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Abstract

This study examined artificial intelligence as a catalyst for career development in teacher education: opportunities, challenges and ethical considerations in the University of Nigeria Nsukka. Specifically, it explored the opportunities AI presents, the challenges hindering its adoption, and the ethical considerations associated with its integration. A mixed-method research design was employed. The quantitative strand involved the administration of a structured questionnaire, the AI in Teacher Education Questionnaire (AITEQ) to lecturers, trainee teachers, and administrative staff, while the qualitative strand utilized open-ended items to capture respondents' insights. The reliability of the instrument was established with a Cronbach's alpha coefficient of 0.80. Data were analyzed using descriptive statistics for the quantitative responses and thematic analysis for the qualitative data. Findings revealed that AI offers significant opportunities for career development, including adaptive learning, professional development, career guidance, and global skill alignment. However, major challenges were identified, such as inadequate infrastructure, insufficient training, weak institutional policies, high costs, and limited curriculum integration. Ethical concerns centered on data privacy, algorithmic bias, fairness, and teacher autonomy. The study concludes that while AI has transformative potential in teacher education, its benefits will only be realized through deliberate strategies that strike a balance between innovation and ethical responsibility. It is recommended that the university strengthen its digital infrastructure, organise continuous capacity building, establish ethical governance frameworks, embed AI into teacher education curricula, and adopt inclusive approaches to ensure equitable access. Human oversight should remain central in all AI-related decisions to preserve professional judgment and accountability.

Keywords: Artificial Intelligence, Career Development, Teacher Education, Opportunities, Challenges, Ethical Considerations

Introduction

Artificial Intelligence (AI) has emerged as a transformative force in global education, reshaping teaching methods, learning experiences, and professional development. Intelligent tutoring systems, adaptive platforms, and learning analytics now enable personalized instruction, automate administrative tasks, and generate data-driven insights that improve outcomes. In teacher education, AI is particularly relevant as a catalyst for career development, equipping educators with innovative tools to address diverse classroom needs and enhance professional growth. Internationally, systematic reviews underscore AI's contributions through conversational systems, immersive technologies, and learning analytics, while also highlighting challenges related to equity and access in resource-constrained contexts (Tan, Cheng & Ling, 2025).

Globally, AI's integration emphasizes sustainability and inclusivity, with personalized learning systems promoting equitable opportunities for learners. Yet, ethical concerns such as bias, transparency, fairness, and human agency remain central to its responsible adoption (Ouyang, Zheng & Jiao, 2023). International organizations, including UNESCO and the European Union, stress the need for ethical frameworks that safeguard inclusivity, privacy, and accountability (European School Education Platform, 2024; Karpouzis, 2024). In teacher education, AI can also support ethical reflection through scenario-based learning that strengthens professional judgment (Weber, Kogler & Holzinger, 2025).

In Nigeria, the promise of AI in education is growing amid reforms to modernize the school system. Initiatives such as the draft National AI Strategy and the AI Academy launched in 2024 represent efforts to foster an AI ecosystem, though challenges of limited infrastructure, professional expertise, and digital divides persist. Studies show that AI can improve science teaching and address workforce skill gaps, but adoption across institutions remains uneven, with many universities lagging behind global trends (Nja, Idiege, Uwe, Meremikwu, Ekon, Erim, Ukah, Eyo, Anari & Cornelius-Ukpepi, 2023). Institutions as leaders in teacher education, are well-positioned to leverage AI through simulation-based training, adaptive platforms, and ethical learning models. However, localized approaches are needed to ensure cultural relevance and to bridge rural-urban disparities (Ogunsekun, Olayemi, Ayanwale & Ajao, 2024).

AI offers significant opportunities for teacher education through adaptive environments, real-time feedback, and simulation-based professional development (Xu & Ouyang, 2021; Nye, 2015). Research from Ghana demonstrates how Generative AI can bridge theory and practice, fostering critical thinking and pedagogical modeling, though caution is advised against overreliance that could limit creativity (Nyaaba, 2024). Yet, persistent barriers ranging from infrastructural gaps and limited expertise to privacy risks and algorithmic bias pose challenges in Africa and Nigeria (Farooqi, Amanat & Awan, 2023). Consequently, while the adoption of AI at various universities in Nigeria provide immense opportunities for career development in teacher education, systemic and ethical considerations must be carefully addressed to ensure sustainable and equitable integration.

Statement of the Problem

Artificial Intelligence (AI) is emerging as a transformative force in education, with potential to enhance teacher training, professional development, and career growth. Globally, AI applications have supported personalized instruction, adaptive learning, and real-time feedback, equipping educators with the skills needed to address diverse and evolving classroom demands.

Despite these prospects, much of the discourse has emphasized student-centered applications, with limited attention to teacher professional development. In developing contexts like Nigeria, AI adoption is constrained by infrastructural gaps, inadequate training, weak policy support, and fragmented institutional initiatives. These challenges limit systematic integration into teacher education, leaving its role in supporting career development underexplored.

Ethical concerns further complicate AI use, including data privacy, bias, and threats to teacher autonomy, which risk exacerbating inequalities in education. Nigerian universities, including UNN, face these realities amid insufficient ethical frameworks. This study addresses a critical gap

by examining the opportunities, challenges, and ethical considerations of AI in teacher education at UNN, and by proposing strategies for its responsible adoption to enhance teacher career pathways.

Purpose of the Study

The primary purpose of this study is to examine AI as a catalyst for career development in teacher education at UNN, focusing on opportunities, challenges, and ethical considerations. Specifically the study aims to:

identify opportunities provided by AI for enhancing teacher training and career progression at UNN.

analyze challenges associated with AI integration in teacher education within the Nigerian context.

explore ethical considerations in AI use, drawing from Nigerian and international perspectives.

propose recommendations for responsible AI adoption at UNN to foster sustainable career development.

Research Questions

The study is guided by the following research questions:

1. What opportunities does AI offer for career development in teacher education at UNN?
2. What are the key challenges in integrating AI into teacher education programs in Nigeria?
3. What ethical considerations arise from AI use in teacher education, and how can they be addressed at UNN?
4. How can AI be ethically leveraged to enhance teacher career pathways in a Nigerian university setting?

Methodology

The study employed a mixed-methods research design, combining quantitative and qualitative approaches to capture both broad patterns and in-depth insights on the role of Artificial Intelligence (AI) in teacher education at the University of Nigeria, Nsukka (UNN). The population comprised teacher educators, trainee teachers, and administrative staff, as these groups offered complementary perspectives on AI adoption and career development. A stratified random sampling technique ensured adequate representation across categories, with a sample of 150 participants consisting of 50 lecturers, 80 trainee teachers, and 20 administrative staff.

Data were collected using two instruments. A structured questionnaire captured quantitative data on opportunities, challenges, and ethical risks of AI adoption through Likert-scale items and open-ended prompts, while a semi-structured interview guide elicited qualitative insights into ethical considerations and strategies for responsible integration. Content validity of the instruments was established through expert review, and reliability was confirmed via a pilot test with 20 respondents, yielding a Cronbach's Alpha coefficient of 0.80, which indicated strong internal consistency.

Analysis was guided by the research questions. Descriptive statistics, including frequency counts, percentages, and mean scores, were applied to examine opportunities and challenges, while thematic categorization was used to analyze open-ended and interview responses. Ethical considerations such as privacy, bias, and autonomy were explored through thematic analysis, and

findings from both strands were integrated to propose strategies for leveraging AI responsibly in teacher education and career development at UNN.

Results and Findings

Research Question 1: Opportunities of AI for Career Development at UNN (Quantitative)

Table 1: Opportunities of AI (Item Means $\pm$ SD; ranked)

Items coded	Item (abbrev.)	Mean	SD
B1	Personalized/adaptive learning for trainees	4.32	0.72
B9	Identifying professional development opportunities	4.28	0.77
B7	Developing 21st-century teaching skills	4.26	0.75
B4	Real-time assessment & feedback	4.21	0.80
B2	Career guidance & growth pathways	4.18	0.84
B6	Strengthening lesson planning & delivery	4.12	0.78
B10	Preparedness for global demands	4.10	0.83
B3	Access to up-to-date resources	4.06	0.86
B5	Collaboration & knowledge sharing	3.98	0.89
B8	Managing diverse classroom needs	3.92	0.88

Interpretation: Respondents strongly endorsed AI's value for personalized learning, PD discovery, and skills for modern teaching (all means ≥ 4.2). Collaborative affordances and support for diverse classrooms are positive but relatively lower (~ 3.9 – 4.0), suggesting room to strengthen communities of practice and inclusive AI-supported pedagogy.

Research Question 2: – Challenges to AI Integration (Quantitative)

Table 2: Challenges of AI Adoption (Item Means $\pm$ SD; ranked)

Items coded	Challenge	Mean	SD
C1	Limited infrastructure (power, internet)	4.34	0.81
C7	High cost of AI tools	4.22	0.87
C2	Lack of teacher training	4.18	0.85
C6	Inadequate technical support	4.09	0.88
C3	Weak institutional policies	4.03	0.90
C9	Curriculum lacks AI integration	3.96	0.92
C8	Poor awareness of AI potential	3.89	0.93
C4	Limited funding	3.87	0.94
C10	Limited government monitoring	3.81	0.96
C5	Resistance to change	3.58	1.02

Interpretation: Infrastructure and cost are the heaviest barriers (means ≥ 4.2). Capacity issues (training, tech support) and governance (policy/curriculum) are substantial (≈ 4.0). Change resistance is present but comparatively lower, implying willingness if enablers exist.

Research Question 3: – Ethical Considerations (Quantitative)

Table 3: Ethical Considerations (Item Means $\pm$ SD; ranked)

Items coded	Ethical Issue	Mean	SD
D10	Need for stronger national/sectoral guidelines	4.36	0.76
D1	Data privacy concerns	4.29	0.79
D8	Lack of transparency in AI decisions	4.18	0.82

D2	Algorithmic bias risks	4.12	0.84
D3	Over-reliance undermines teacher autonomy	4.05	0.88
D6	Accountability for AI-assisted decisions	4.01	0.86
D5	Equity gaps between well/under-resourced units	3.98	0.91
D4	Weak ethical frameworks in education	3.96	0.90
D7	Reduced human interaction	3.85	0.95
D9	Job security concerns	3.52	1.03

Interpretation: Strongest concerns are governance (need for clear guidelines), privacy, and transparency/bias. Fears about job displacement are moderate, but teacher autonomy and accountability need explicit protections.

Table 4: Thematic Coding of Open-Ended Responses (Frequencies; $n = 150$)

Theme (Open-Ended)	Example Focus	Count
Personalized & adaptive learning	Tailored feedback, mastery-based pacing	104
Faculty/trainee capacity building	Short courses, micro-credentials	96
Infrastructure & cost	Power, connectivity, licenses	91
Ethical/data governance	Privacy, consent, transparency	83
Curriculum embedding	Methods courses, practicum tools	76
Support services	Tech help-desk, sandbox labs	68

Interpretation: The open-ended data reinforce the Likert findings: respondents most frequently request personalized learning and capacity building, with infrastructure and ethics the most salient constraints.

Qualitative Findings (SSIG)

Theme 1: Adaptive Learning & Analytics as Career Accelerators

What emerged: Participants view AI-enabled adaptive platforms and learning analytics dashboards as catalysts for faster skill acquisition, reflective practice, and portfolio-ready evidence (e.g., analytics-backed micro-credentials).

Interpretation: There is strong pull for evidence-rich professional development; graduates want data to showcase competencies.

Theme 2: Infrastructure & Cost as Gatekeepers of Equity

What emerged: Unreliable power/connectivity and tool costs hamper continuity; students often revert to manual workflows.

Interpretation: Adoption will stall without stable infrastructure; equity gaps widen when access is inconsistent.

Theme 3: Capacity & Confidence Gaps among Staff/Trainees

What emerged: Many feel under-prepared to integrate AI in lesson design and assessment; desire hands-on, classroom-situated training.

Interpretation: Confidence—not just knowledge—is a barrier; practice-based training beats theory-only workshops.

Theme 4: Ethics by Design — Privacy, Bias, and Teacher Autonomy

What emerged: Strong calls for clear rules on data use/consent, human oversight, and bias checks; concerns about being overruled by opaque systems.

Interpretation: Trust hinges on transparent, teacher-centered governance.

Theme 5: Curriculum Integration & Practicum Use-Cases

What emerged: Participants want AI woven into methods courses, micro-teaching, and practicum simulations (e.g., classroom scenarios).

Interpretation: Impact rises when AI is embedded, not optional.

Theme 6: Support Ecosystem — Help-Desk, Fellows, and Communities

What emerged: Requests for rapid support (help-desk), AI-in-Education fellows, and peer communities.

Interpretation: Sustained adoption needs a service layer and peer learning.

Discussion of Findings

Respondents perceived AI as highly beneficial for personalized learning, professional development, and building 21st-century teaching skills (mean ≥ 4.2). This aligns with Xu and Ouyang (2021) and Nye (2015), who argue that intelligent tutoring systems, adaptive platforms, and learning analytics foster individualized instruction and scaffold teacher growth. Similarly, Tan, Cheng, and Ling (2025) highlight conversational AI and immersive tools as pathways for pedagogical innovation. This implies that UNN should prioritize adaptive-learning pilots and analytics-driven professional development to transform these perceived opportunities into structured and accredited growth pathways.

The strongest barriers reported were unstable infrastructure, high costs, and limited teacher training (means ≈ 4.2 – 4.3). This reflects findings in developing contexts where deficits in electricity, internet, and human capacity constrain technology adoption (Farooqi, Amanat & Awan, 2023). Nigerian studies confirm that fragmented implementation and low readiness remain significant barriers (Nja et al., 2023; Ogunsekun, Olayemi, Ayanwale & Ajao, 2024). This implies that UNN should sequence AI implementation by stabilizing infrastructure and investing in continuous capacity-building before large-scale procurement of tools.

High concern was expressed about data privacy, transparency, and algorithmic bias, with strong endorsement of the need for guidelines. This is consistent with Ouyang, Zheng, and Jiao (2023), who argue that responsible AI requires fairness, privacy, and transparency, as well as UNESCO and EU frameworks emphasizing ethics-by-design (European School Education Platform, 2024; Karpouzis, 2024). Cotton et al. (2023) and Weber, Kogler, and Holzinger (2025) further warn of risks to autonomy and accountability without governance safeguards. This implies that UNN should establish a comprehensive AI ethics and data governance framework covering privacy, consent, bias-auditing, and teacher autonomy.

Both quantitative and qualitative results revealed a demand for embedding AI into methods courses, practicum simulations, and assessment rather than treating it as add-on training. This accords with Nye (2015) and Xu and Ouyang (2021), who stress alignment of technology with curriculum for lasting impact. Nyaaba (2024) further shows that generative AI and simulations are

most effective when bridging theory with practice through reflective tasks. This implies that UNN should map AI tools directly to course outcomes and embed them into practicum activities to strengthen trainee teachers' applied competencies.

Resistance to change was rated lower than infrastructure and training challenges, indicating readiness to adopt AI if enabling supports exist. This reflects Tan et al. (2025) and Farooqi et al. (2023), who note that teachers' openness increases when capacity-building, technical support, and policies are provided. Xu and Ouyang (2021) similarly show that attitudes improve when AI use is classroom-oriented. Nigerian policy efforts like the draft National AI Strategy suggest enabling direction, though institutional supports remain vital (Nja *et al.*, 2023; Ogunsekun et al., 2024). This implies that UNN should establish visible supports such as training pathways, help-desks, and AI fellows to convert willingness into sustainable practice.

Respondents highlighted the risk that AI adoption could widen inequalities between well-resourced and under-resourced units (mean ≈ 3.98). This supports evidence that AI may exacerbate disparities when infrastructure and resources are unevenly distributed (Farooqi et al., 2023; Ouyang et al., 2023). Nigerian studies echo that urban–rural and institutional divides may deepen without deliberate inclusion strategies (Nja et al., 2023; Ogunsekun et al., 2024). This implies that UNN should design inclusive AI rollouts by providing low-bandwidth solutions, shared labs, and subsidized access to ensure equitable benefits across the university.

Summary of Findings

This study investigated artificial intelligence (AI) as a catalyst for career development in teacher education at the University of Nigeria, Nsukka (UNN): opportunities, challenges, and ethical considerations.

Opportunities: AI was widely perceived as a transformative enabler of career development. Respondents strongly agreed that AI can support personalized learning, facilitate real-time assessment, enhance lesson planning, provide career guidance, and foster the development of 21st-century teaching skills.

Challenges: Infrastructure limitations, inadequate teacher training, insufficient policies, high cost of AI tools, and lack of technical support emerged as the most critical barriers. Participants also highlighted limited curriculum integration and weak government monitoring as obstacles.

Ethical Considerations: Respondents expressed strong concern about data privacy, algorithmic bias, reduced teacher autonomy, lack of transparency, and the potential for AI to widen institutional inequalities. There was consensus on the urgent need for robust ethical guidelines to regulate AI in teacher education.

Responsible Leveraging of AI: Qualitative findings revealed that stakeholders believed AI should be integrated into curriculum and practicum activities rather than treated as optional add-ons. Participants also stressed the importance of human oversight, transparency, and institutional policies to ensure AI adoption supports, rather than undermines, teacher career development.

Conclusion

The study concludes that AI offers significant opportunities for advancing career development in teacher education at UNN by enhancing adaptive learning, professional growth, and global preparedness. However, infrastructural constraints, limited training, weak institutional policies, and ethical concerns present substantial barriers to effective adoption. Without deliberate strategies, AI risks reinforcing inequities and undermining educational integrity. Thus, while AI has the potential to transform teacher education, its benefits will only be realized if universities adopt a balanced approach that strengthens infrastructure, embeds AI in curriculum and practicum, and upholds ethical principles of fairness, transparency, inclusivity, and accountability.

Recommendations

Based on the findings, the following recommendations are made:

UNN should strengthen digital infrastructure (stable internet, electricity, and affordable AI tools) and provide sustained technical support for staff and trainees.

The university should organize continuous professional development programs on AI literacy, focusing on practical classroom integration and ethical use.

Institutional and national education authorities should develop and enforce ethical frameworks for AI in teacher education, including data protection, transparency, and accountability mechanisms.

AI should be embedded into methods courses, practicum simulations, and assessment frameworks, ensuring it directly supports teacher professional competencies.

The university should adopt inclusive strategies, such as subsidized AI access, low-bandwidth solutions, and shared resource centers, to ensure that AI adoption does not deepen existing disparities.

AI adoption should remain human-centered, with lecturers and administrators retaining decision-making authority to safeguard teacher autonomy and uphold professional judgment.

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COMPARATIVE ANALYSIS OF THE EFFECTS OF TRADITIONAL JIGSAW AND MODIFIED JIGSAW ON STUDENT ACHIEVEMENT IN MATHEMATICS: A REVIEW WITH IMPLICATIONS FOR INTEGRATING ARTIFICIAL INTELLIGENCE IN EDUCATION

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Abstract

This paper presents a focused literature review comparing the effects of the Traditional Jigsaw (TJ) and Modified Jigsaw (MJ) learning approaches on student achievement in mathematics, and draws implications for integrating Artificial Intelligence (AI) into jigsaw-based instructional designs. We synthesize systematic reviews, meta-analyses, experimental and quasi-experimental studies, and recent AI-in-education reviews to (a) summarize evidence for TJ and MJ in mathematics contexts, (b) identify mechanisms that explain differential effects, and (c) propose principled ways AI can strengthen MJ while protecting social learning processes. The review finds that both TJ and MJ can improve engagement and learning over textbook/lecture-only approaches when implemented with fidelity; however, MJ variants that add scaffolds, role structures, and formative assessment typically yield more consistent mathematics achievement gains. AI offers scalable, targeted supports (adaptive scaffolding, automated formative feedback, analytics-driven group formation) but requires careful design for equity, transparency, and preservation of peer interaction.

Keywords: *Jigsaw, mathematics achievement, modified jigsaw, artificial intelligence, adaptive learning*

Introduction

Cooperative learning methods have long been championed for improving academic achievement and social skills (Johnson & Johnson, 1989; Slavin, 1995). The jigsaw technique where students become “experts” on subtopics and then teach peers was introduced to promote interdependence and reduce competition (Aronson, 1978; Aronson & Patnoe, 1997). In mathematics education, jigsaw has been used to teach complex multi-step topics (e.g., algebraic problem solving, geometry proofs) by dividing topics into interlocking subskills.

Practitioners and researchers have introduced modified jigsaw variants that add teacher scaffolds, technology-mediated supports, formal rubrics, role rotation, and blended or flipped elements to address observed challenges with student readiness, fidelity of peer teaching, and assessment. With the emergence of AI in education, there is an opportunity to integrate intelligent supports into jigsaw designs optimizing group formation, providing adaptive scaffolding, and automating feedback. The jigsaw classroom originally developed by Aronson and colleagues in the 1970s asks students to become “experts” on parts of a topic, meet with peers holding the same part, and then return to teach their home group. It was originally conceived to promote cooperation and to reduce intergroup conflict; since then, it has been widely adapted across subjects, including

mathematics. Researchers and practitioners have created many modified jigsaw variants that introduce teacher scaffolds, explicit roles, rubrics, technology-mediated supports, or blended-flipped formats to address limitations observed in practice (uneven preparation, propagation of misconceptions, low accountability). This review synthesizes the empirical literature to compare TJ and MJ outcomes in mathematics achievement and then maps the findings onto opportunities and cautions for AI-supported implementations.

Methods

This is a narrative/systematic-informed review focused on peer-reviewed empirical studies, meta-analyses, and recent systematic reviews (2018–2025) addressing jigsaw implementations and AI applications in education. Searches combined terms such as “jigsaw classroom,” “modified jigsaw,” “jigsaw mathematics,” “cooperative learning meta-analysis,” and “artificial intelligence in education review.” Highly cited systematic reviews and recent empirical studies were prioritized to capture both foundational and contemporary evidence. Because “modified jigsaw” is heterogeneous, we coded MJ papers by the primary modification reported (scaffolding, role definition, technology integration, assessment). Where possible, mathematics-specific results were highlighted. Key sources include recent systematic reviews of jigsaw studies and major AI-in-education syntheses.

Conceptual definitions

Traditional Jigsaw (TJ): The canonical expert/home-group arrangement with minimal teacher-provided scaffolds beyond topic division and process explanation.

Modified Jigsaw (MJ): Any variant of jigsaw that intentionally modifies the original procedure by adding scaffolds (worked examples, guided notes), explicit role assignments (recorder, questioner, checker), assessment tools (rubrics, formative quizzes), or technology (LMS, multimedia, discussion forums). Because MJ is an umbrella term, effects depend strongly on the specific components implemented.

Empirical evidence: TJ and MJ effects on mathematics achievement

Overall pattern from meta-analyses and systematic reviews

Large-scale syntheses of cooperative-learning and jigsaw-specific studies report mixed-to-positive effects on learning. Meta-analyses of cooperative learning generally find small-to-moderate positive effects on achievement when group goals and individual accountability are present; jigsaw as a method appears beneficial in many contexts but is sensitive to fidelity and context. Recent systematic work gathering jigsaw studies (including education and health-education domains) indicates that jigsaw tends to improve learning and engagement compared to some control conditions, but effect sizes vary widely across studies and subjects.

Mathematics-specific experimental and quasi-experimental studies

Multiple quasi-experimental and experimental studies in mathematics across secondary and tertiary contexts report gains when jigsaw (TJ) is used instead of teacher-centered instruction. For example, studies in secondary mathematics settings observed higher posttest scores and increased interest after jigsaw interventions compared with traditional lecture; however, several more tightly controlled experiments and replication attempts have produced small or null effects, particularly when TJ fidelity was low or when complex topics required deeper scaffolding than peer

explanation alone could provide. These mixed empirical outcomes have motivated MJ developments that intentionally address sources of variability (preparation, accountability, content complexity).

Evidence favoring Modified Jigsaw

Studies comparing TJ with MJ variants (or comparing MJ against lecture/TJ combined) frequently report superior mathematics outcomes for MJ models that include targeted scaffolding (worked examples, structured expert packets), role clarification with rubrics, and integrated formative assessment. MJ reduces the risk that an unprepared “expert” will teach incorrect procedures, and its scaffolds often reduce extraneous cognitive load during peer teaching an important consideration in mathematically dense topics where cognitive load can impair transfer and conceptual coherence. Recent reviews and experimental reports show MJ’s consistency in producing gains is higher than TJ’s when implementation quality is reported.

Boundary conditions & heterogeneity of effects

Content complexity: For highly procedural or multi-step problem solving, MJ with worked-examples and guided reflection is more effective than TJ.

- Teacher training/fidelity: Both TJ and MJ require teacher orchestration skills, but MJ’s explicit materials help maintain fidelity across less experienced teachers.
- Class size & grouping: Cooperative benefits attenuate in overly large groups; small group sizes (3–6) are typical for optimal jigsaw functioning.
- Assessment & accountability: Studies emphasize that the presence of individual accountability (quizzes, graded contributions) amplifies achievement effects.

Mechanisms explaining differential outcomes (theory + evidence)

Three interacting mechanisms account for why MJ often outperforms TJ in mathematics:

1. Cognitive load reduction through scaffolding: Providing worked examples and structured expert materials helps student-experts form accurate mental models before teaching, reducing error propagation during peer instruction. This aligns with cognitive load theory.
2. Increased individual accountability and clearer success criteria: Role structures and rubrics make contributions visible, motivating preparation and careful explanation. Empirical reviews link these features to larger effect sizes.
3. Faster misconception detection and correction: Formative checks (quick quizzes, teacher spot-checks, peer checks) embedded in MJ provide feedback loops that prevent persistent misunderstanding crucial in cumulative subjects such as mathematics.

Integrating Artificial Intelligence: Opportunities grounded in the literature

Why AI is relevant to MJ

AI and related technologies (intelligent tutoring systems, adaptive sequencing, learner analytics, NLP-based feedback) can automate and scale several MJ components that studies show matter for achievement: adaptive scaffolding, quick formative feedback, and data-driven grouping. Recent systematic reviews of AI in education document robust gains from adaptive and ITS approaches, particularly when individualized practice and immediate feedback are available. Integrating AI

into MJ is thus a promising pathway to maintain MJ fidelity and personalize support without overburdening teachers.

Specific AI affordances for MJ (evidence-informed)

Adaptive expert-preparation modules: AI-driven micro-tutors can scaffold each student's expert learning sequence (worked-example fading, targeted hints) so peer-experts reach required mastery before teaching. Systematic ITS reviews show strong learning effects for well-designed adaptive modules.

Automated formative feedback: Short, automated assessments with diagnostic feedback can rapidly flag misconceptions for teacher or group remediation. Evidence from ITS and adaptive assessment literature indicates improved learning with immediate, diagnostic feedback.

Analytics-informed group formation: Algorithms can suggest heterogeneous groups optimized for complementary skills, prior achievement, or social dynamics reducing ad hoc groupings that undermine cooperative learning. Evidence on analytics use is growing; however, fairness and transparency must be considered.

Support for peer-teaching quality: NLP analysis of student explanations (text or speech) can surface common errors or conceptual gaps to teachers, enabling targeted interventions. This use case is emergent and requires careful validation.

Risks, ethical considerations, and practical constraints

- **Erosion of social processes:** Over-reliance on automated explanations can reduce student-to-student dialog and the pedagogical benefits of peer teaching; AI should complement not replace peer interaction.
- **Data privacy and consent:** Learner analytics and ITS collect sensitive performance data; privacy protections, clear consent processes, and minimal data retention principles are required.
- **Algorithmic bias:** Grouping or adaptive recommendations must be audited to avoid reinforcing inequities (e.g., tracking).
- **Infrastructure and access:** Low-resource settings may lack devices or reliable connectivity; low-tech MJ modifications should remain available.
- **Teacher capacity:** Effective AI-MJ integration requires teacher professional development for interpreting analytics and orchestrating AI-augmented activities.

Practical recommendations for researchers and practitioners

For practitioners (classroom & school leaders)

1. Adopt MJ with targeted scaffolds for complex math topics. Use worked examples, explicit role rubrics, and short formative checks embedded in each jigsaw cycle. Evidence shows these features increase consistency of achievement gains.

2. Pilot low-risk AI features first. Begin with automated quizzes and adaptive preparatory modules that help each student reach a minimum mastery before peer teaching. Monitor outcomes and student perceptions.
3. Maintain human oversight. Ensure teachers review AI recommendations (grouping or feedback) and retain final control over instructional choices to preserve social learning goals.

For researchers

1. Run componential RCTs of MJ. Because MJ is heterogeneous, dismantling studies are needed to isolate which components (scaffolds vs. roles vs. formative feedback vs. AI supports) drive gains in mathematics.
2. Evaluate AI-augmented MJ in diverse contexts. Conduct rigorous trials of AI supports across resource settings and grade bands, examining equity outcomes and fidelity.
3. Measure process outcomes. Capture peer-explanation quality, dialog patterns, and teacher orchestration time alongside achievement to understand mechanisms of change.

Limitations of this review

This review prioritized recent systematic reviews, meta-analyses, and selected empirical studies but is not a fully exhaustive systematic review with formal inclusion/exclusion criteria and PRISMA reporting. The term “modified jigsaw” covers diverse interventions, which complicates direct comparisons. Finally, AI-in-education literature is rapidly evolving new ITS and analytics studies continue to appear (2024–2025), so ongoing syntheses will be needed.

Conclusion

The jigsaw approach remains a valuable cooperative-learning strategy. Evidence indicates that Modified Jigsaw variants those that intentionally add scaffolding, role clarity, and formative assessment produce more consistent mathematics achievement gains than Traditional Jigsaw, particularly for complex or procedural content. AI can amplify MJ’s strengths by delivering adaptive scaffolds, automated formative feedback, and analytics-informed grouping, but should be integrated carefully to preserve essential social processes, ensure equity, and build teacher capacity. Future research should isolate MJ components and evaluate AI-augmented MJ designs with rigorous, equity-focused trials.

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ENRICHING THE KNOWLEDGE OF WOMEN ON THE RHESUS FACTOR THROUGH ARTIFICIAL INTELLIGENCE: THE LIBRARIAN'S PERSPECTIVE

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Abstract

Empowering women with the knowledge of Rhesus factor is significant in determining the maternal and neonatal health of women especially pregnant women. In spite the critical role Rhesus factor played in maternal and neonatal health, the knowledge and awareness level of many women remains very low in low income and underserved countries. Most especially on incompatibility, risk and prevention. This paper, however, contends that Artificial intelligence can be used as a transformative tool in filling the knowledge gap amongst women. Platforms powered by Artificial intelligence such as: Chabots, mobile health applications, predictive analytics to telemedicine, gamification and conversational agents could be used to convey personalised, accessible, data-driven and culturally sensitive information to women about Rh. factor and its implications. In addition, the role of librarians in this situation is multifaceted; they are strategically stationed to curating information and promoting Artificial intelligence resources to support women health literacy especially before the occurrence of pregnancy complications. Hence, enabling women to make informed reproductive health decision, ultimately preventing maternal and neonatal complication. This paper advocates for a stronger alliance between health professionals, Artificial Intelligence developers and information specialists to create digital tools and ensure ethical and effective health education. Providing women with the right information at the right time through artificial intelligence is not just a step ahead but also socially imperative.

Keywords: Rhesus factor, women, knowledge, Information, health professionals.

Introduction

The integration of women's health and technology is a crucial frontier required in addressing the persistent gap in awareness and knowledge of several health matters. A typical example of such gap rests on understanding the Rhesus factor (Rh) factor condition which is a life-threatening blood antigen that affects pregnancy outcomes most especially in developing countries (Abd Elhakim *et al.*, 2024; Geta *et al.*, 2024). For instance, Abd Elhakim *et al* (2024) research work from Assiut University exhibited that only 19.7% of women showed good knowledge about RH factor and its consequences, whereas, 58.7% had very poor knowledge. Similarly, in Ethiopia, only 48% of pregnant women knew their blood group while only 35.3 % of women showed adequate knowledge regarding Rh incompatibility (Geta, *et al.*, 2022). In addition, a research work from Irrua, in Nigeria revealed only 17.2 percent of respondents were fully aware of the Rh factor while 39.1 had good level of knowledge. However, more than 60% had never heard of Anti-D prophylaxis and 51.6% mistakenly believed Rh incompatibility cannot be prevented (Onyejose *et al.*, 2023). Furthermore, Obiora *et al* (2023) highlighted that only 46.9% of respondents understood that Rh incompatibility could lead to complications such as: abortion or pre mature birth, and only 53.1 mistakenly knew when the shot should be given. This dearth of knowledge can lead to complications that can easily be prevented such as hemolytic disease of newborn or death (Júnior

et al., 2024; National Blood Authority, 2024). However, in today's era of technological advancement, artificial intelligence stands as rigid transformative tool that can be used to close the gap (Mapari, Chandanwale, and Raut,2024; Till *et al.*, 2023).

Artificial intelligence which has the ability to deliver personalised, user-friendly, interactive and on-demand information has served as alternative to the traditional health campaigns which have failed to engage women regularly or blend to their varying literacy and access needs. This paper offers a fresh and professional perspective on why it is paramount to equip women with knowledge on Rh. factor using Artificial intelligence as a transformative alternative and why librarians should at the forefront of this initiative.

Despite the effect of Rhesus factor on maternal and neonatal well bring, the term remains unknown to many women globally. This lack of awareness arises from a confluence of factors, such as; insufficient health literacy, poor ante-natal education, socio-economic and structural barriers, misinformation and cultural beliefs, language and cultural barriers and lack of educational support. For instance, a qualitative study revealed women misunderstood the purpose of antenatal care, thinking it a curative instead of a preventive measure. As a result, they miss vital information such as Rhesus factor screening (Ndidi and Oseremen, 2019). This depicted that health education during antenatal care does not often cover detailed topics like Rh factor management. Similarly, a systematic review revealed women usually have lower literacy level and are not served by good health education interventions (Nawabi *et al.*, 2024). This showed that language barrier affects women whose first language does not tally with the health workers own. In addition, a study in Egypt shows low literacy as a significant barrier, Research from (Elbarazi *et al.*, 2022) shows the literacy level of pregnant women was 79.8 percent which was associated with lower education, income and unplanned pregnancies. It is however glaring that the earlier mentioned limitations affect women's ability to comprehend information about blood groups, Rh, factor and the available preventive interventions (Nawabi *et al.*, 2024). Ideally, in localities where health education is uncommon, the repercussions may be severe there by causing complications such as Rh incompatibility leading to hemolytic disease of newborns, which in critical cases can lead to illness or death. This gap in knowledge gives emphasis to the need for innovative educational tools that surpasses the orthodox barriers.

Artificial intelligence has enhanced how health information is been adapted and communicated in specific contexts and situations (Chu & Liu, 2025; Lim & Schmälzle, 2023; Miller, 2024). Platforms driven by artificial intelligence such as chatbot and mobile applications like voice assistants and whatsapp-bots have the ability to answer questions in any language which will be effective in breaking language barrier. Personalised reminders such as a pop-up message notification on when next you are supposed to take your anti-D injection can also increase compliance. Similarly, myths and misconceptions about Rh factor can be addressed by issuing prompt evidence-based responses. In addition, to minimize missed chances for prevention to the barest minimum, Artificial Intelligence powered health decision support systems can be used to automatically flag Rh negative mothers from their available antenatal data bases. This decision support system can also alert health workers when a patient's Anti-D prophylaxis is due to enable them follow up on patients and the necessary interventions offer.

Moreover, artificial intelligence is embedded with Natural Language Processing (NLP) which enables the computer to read, understand translate, interpret, generate and reply in human language. This element if embedded by health workers will help design awareness messages that are not just sensitive but culturally inclined. In addition, it can also enable social media which is also a delicate tool for effective communication in this 21st century to detect misinformation about Rh factor conditions.

Artificial intelligence can also bridge the gap between health professionals and women, especially those in purdah, with telemedicine platforms, these women can receive guidance on Rh status without their frequent presence in the hospital environments. As most of these women have access to phones, developing animated stories, comedies, quizzes and other gamification and interactive educational modules can be structured in their local dialects to educate them about their blood groups, Rh incompatibility, and preventive measures. This will make learning not just engaging but will enhance their retention of information. Furthermore, Artificial intelligence driven tools can also recognise at risk mothers, that is mothers that are RH-negative, missed screening, or with unknown partners via predictive analysis. It can also predict likely complications and allocate resources such as when the Anti-D immunoglobim supply is required the most.

Interestingly, Artificial intelligence fueled chatbots have been used globally to checkmate health issues globally, examples are Ada Health, which is a globally used Artificial intelligence driven syptom checker that offers health information (Daylox,2025) , we also have Viz.ai that also analyzes Comouted Tomography scans (CT scan) to detects potential issues such as strokes. It also notify specialists by minimising delays in treatment (Arkenea, 2025). In addition, Myna Mahila Foundation chatbot has also been very helpful to women in Mumbai for delivering reproductive health advice (AP News, 2023). In Nigeria, several Artificial intelligence chabots are also in operation such as; Trust help care which offers personalised health guidance (punch, 2024), we also have Platos Body Monitor distributed via pharmacies in Nigeria to track hidden health risks such as diabetes. In addition, ChatDr, is also an Artificial intelligence driven chatbot that analyses symptoms, offers personalised support. It is however glaring that artificial intelligence cannot replace human care but has gone a long way in empowering them to stay informed, with current evolving medical guidelines and engage more with healthcare providers. To further enhance these, there is a pressing need for digital health literacy interventions that can fill the knowledge divides and empower women with current, evidence-based life-saving information.

In addition, librarians basically known as the custodians and curators of knowledge could also be described as ambassadors of digital health literacy. In this regard, their proficiency in information organisation, retrieval and evaluation gives them an edge in combating misinformation and ensuring evidence –based access to health information in any formats. According to Okan *et al.* (2022) digital health literacy is paramount for the attainment of equity in the health sector making experts who are skilled in guiding people through digital information ecosystems indispensable. Librarians however, can select, organise and present reliable maternal information resources, apply Artificial intelligence enabled health education platforms and collaborate with health care providers to raise more awareness on Rh incompatibility and preventive measures.

In Nigeria and other low and middle income countries, librarians are strategically found within universities, hospitals and community libraries charged with the task of providing services to

underserved populations. Their involvement in health information campaigns feed women with information on maternal health risks, including RH incompatibility and issues associated with it. This is supported by Pangrazio and Sefton-Green (2023) who revealed that empowering women with knowledge on the use of digital platforms is essential and librarians can mitigate the gap between technology and health awareness. In reality, librarians have gone beyond the passive providers of information and have upgraded to co-creators, evaluators and advocates in the artificial health ecosystem.

While Artificial intelligence holds a great promise, in filling the gap on maternal health conditions such as Rh. Factor, some ethical and practical challenges needs to be addressed to ensure safe and equitable adoption. Challenges such as: data privacy and security, since artificial Intelligent driven platforms rely on sensitive personal data, without robust protection, women risk breaches of confidentiality, discrimination based on health information and even misuse of health data. However, compliance with international standards like General Data Protection Regulation (GDPR) and upholding the transparent data governance are vital steps that can be taken. (Kostkova, 2023; Obasola &Agunbiade, 2023). Additionally, since most Artificial intelligence tools often rely on data which they are given, they may generate misleading information when exposed to poor quality or biased algorithms. Librarians and information professionals and health workers, however, have a great role to play in verifying Artificial intelligence outputs, curating authoritative sources and mentoring users on how to analytically assess digital health gadgets (Haleem et al, 2022; Hoving,2024). Furthermore, there is a wide gap between the urban and rural settlers regarding accessibility, Internet availability, digital skills and health literacy likewise in low and middle income countries. Rural settlers are more at risk of maternal health issues, hence may face challenges of adopting artificial intelligence chat bots, tools such as smartphones, affordable data and training may be a barrier (Olanrewaju et al;2022;Adegboye &Vaidhyamp,2024). Bridging this divide may require more expertise, offline capabilities and community based digital literacy programmes that will motivate and empower women to access and benefit from this Artificial intelligence interventions.

To professionally tackle the maternal health knowledge gaps, especially on rhesus factor using artificial intelligence, there is a pressing need for multi-stakeholder collaboration among health professionals, libraries, technological inventors and policy makers. Health providers can function in providing accurate content and clinical expertise. In addition, libraries as curators of information can serve as reliable access points to accurate health information while inventors are charged with the production of Artificial intelligence driven applications that are culturally relevant, user friendly and tailored towards women needs. Lastly, the regulatory frameworks and funding that fuels Artificial intelligence adoption in health education are functions of policy makers. To achieve the required success, the government, institutions, and Non governmental organisations (NGOs) and other governing councils must support artificial intelligence and other digital literacy programmes that will enable women engage with credible health technologies and minimise to the barest minimum, misinformation (Kaur&Rani; Adegboye &Vaidhyamb, 2024)

In addition, pilot projects or study can determine impact and inform best practices on the effectiveness of artificial intelligence tool on Rhesus factor. For instance, a pilot study or practice can be adopted involving libraries, health professionals and NGOs and Information Technological experts to test innovative Artificial intelligence based campaigns and awareness such as: mobile

applications, chat bot, sms notification, before broadening it to a larger population (Haleem, et al.,;Olanrewaju et al., 2022). As a team, if these actions are fully implemented, they will bring sustainable improvement on maternal health literacy and outcomes especially on Rhesus factor. It will also ensure that the information disseminated is accurate, culturally relevant and technologically all encompassing (Obasola&Agunbiade, 2023; Hoving, 2024)

By and large, to reduce to the barest minimum the knowledge gaps surrounding RH factor, there is a pressing need for collaboration among libraries, health educators, IT professionals and policy makers. Institutional involvement in Ai driven literacy initiatives coupled with a rapid implementation of pilot studies and community awareness campaigns will be important in empowering women with health information that is not only accessible but also accurate timely (Adegboye & Vaidhyamb, 2024; Kaur & Rani, 2023). Such deliberate and coordinated efforts have the potential of reducing maternal health challenges such as Rhesus factor related complications.

Conclusion

This article concluded that Artificial intelligence if well guided by informed professionals like librarians can meaningfully increase women's knowledge and awareness on rhesus factors and its underlying implications. Artificial intelligence tools offer the technical ability to personalise, enhance, scale and simplify health education, librarians offer credibility, authority, trust and professionalism to bridge the gap between technology and users. The confluence of these assets can revolutionise maternal health education from the patchy awareness into knowledgeable empowerment of Rhesus factor risks and complications.

Looking ahead, embracing Artificial intelligence is not just a technological upgrade, it is a commitment. The implementation of artificial intelligence driven tools into maternal health matters such as rhesus factor will not only close the persistent knowledge gap but also build a future where all women will be skilled, well informed and confident about their health matters. In addition, with collective promise and strategic use of artificial intelligence, coupled with the helping hands of librarians and health educators the vision of reducing to the nearest minimum preventable pregnancy complications will not only be realistic but attainable. This is not merely an academic proposal but a call to act in advancing equity and fostering healthier, knowledgeable and smart generation women.

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INTEGRATING ARTIFICIAL INTELLIGENCE INTO ELECTRICAL/ELECTRONIC TECHNOLOGY EDUCATION: A STRATEGIC FRAMEWORK FOR BUILDING A SKILLED AND INNOVATIVE WORKFORCE IN ZAMFARA AND KATSINA STATES

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Abstract

This study investigated the integration of AI into Electrical/Electronic Technology Education in Nigerian Colleges of Education to enhance teaching, learning, and workforce skill development. A descriptive survey design was adopted, and the population comprised all lecturers of Electrical/Electronic Technology from selected Colleges of Education in Zamfara and Katsina States. A structured questionnaire was used to collect data from 19 lecturers, and responses were analyzed using mean, standard deviation, and t-test. Findings revealed that while the current state of Electrical/Electronic Technology Education moderately supports workforce skills development, lecturers strongly agreed that AI could enhance teaching, learning, and innovation. There was also strong support for developing a strategic framework to guide AI integration. The t-test indicated no significant difference in perceptions between lecturers across the two states. The study concludes that AI has the potential to transform technical education in Nigeria, but its effective adoption requires deliberate planning, policy support, teacher training, adequate infrastructure, and industry collaboration. Recommendations include integrating AI into teaching practices, establishing a strategic framework, and strengthening industry partnerships to prepare a skilled and innovative workforce.

Keywords: Artificial Intelligence, Electrical/Electronic Technology Education, Technical Education, Workforce Skills, Strategic Framework, Nigeria

Introduction

Electrical/Electronic Technology Education (EETE) encompasses the preparation of a skilled workforce signified by different kinds of occupations that can sustain the industrial induction, techno-scientific innovation, energy and power, and digital infrastructure requirements of nations. In other words, it plays a key role in ensuring ongoing socio-economic development. In Nigeria, where the economy wants to diversify away from oil dependence, the mandate of EETE in the preparation of technicians, engineers, and innovation has never been more pressing (Zite & Deebom, 2021). However, despite the importance of EETE, it is faced with perennial challenges that stem from outdated curricula, insufficient teaching and learning resources, lack of effective partnerships with industry, ineffective pedagogical models, and lack of innovation. These issues contribute to a workforce that often does not meet the challenges of the 21st-century labor market. Artificial Intelligence (AI) presents a viable avenue for addressing these deficits. In contrast to traditional teaching practices which rely on rote skills knowledge and controlled practice, AI technologies such as intelligent tutoring systems, machine learning systems, virtual labs, and predictive analytics could provide a more dynamic, interactive and competency-based EETE (Ali *et al.*, 2025). AI establishes learning contexts that resemble the application of learning to the world through personalized instruction, real-time feedback, and simulated industrial processes. We

believe this shift can strengthen more than just the technical skill base; it fosters creativity, problem-solving, and critical thinking; skills and capacities valued in innovation and ushering entrepreneurs (Zary & Zary, 2025).

The ramifications of the transition to artificial intelligence in engineering and technology education (ETE) have considerable significance for Nigeria. The countries' rates of unemployment and underemployment among technically trained workers remains extremely high, primarily, because there is a gap between the skills acquired in-school compared to those expected of them in practice (Gupta *et al.*, 2023). Artificial intelligence in EETE can help close the gap between educational outcomes and labor market needs while developing students' digital fluency. Furthermore, AI has the potential to facilitate greater collaboration between educational institutions and industry, by supplementing areas such as data-informed decision-making, predictive workforce planning and incubation of entrepreneurial opportunities (Wan, 2024). Therefore, the use of all will not simply be a technological enhancement, it is a strategic lever to enhance a workforce in post secondary education that is innovative and competitive.

However, the process of AI integration is fraught with challenges, including infrastructural inadequacies, teacher's levels of digital readiness, a high cost of implementation, and ethical issues around automation (UNESCO, 2021). Unless these challenges are addressed Nigeria will face a greater risk of widening its digital divide with technologically advanced countries. Hence AI integration in EETE will require not only investment in digital technologies but also investment in policy, curriculum development, teacher training, and teamwork with industry stakeholders. It is against this backdrop this study seeks to examine the integration of Artificial Intelligence in Electrical/Electronic Technology Education and develop a strategic framework for building a skilled and innovative workforce in Nigeria. By critically acknowledging the opportunities and challenges, the study suggests that AI will provide opportunities for reshaping technical education and address sustainable development for the nation.

Statement of the Problem

Electrical/Electronic Technology Education (EETE) in Nigeria is projected to provide the basis for a skilled workforce which will lead to industrialization, innovation, and national development. However, despite the significance of EETE, the constraints of outdated curricula, insufficient pedagogical materials, poor industry relationships, and traditions from prior pedagogical approaches that emphasize theoretical over practical activities still apply (Zite & Deebom, 2021). These deficits have perpetuated the gap between the skills which technical graduates possess and the skills necessary to succeed in the workplace, as evidenced in the high rates of unemployment and underemployment of young people (Gupta *et al.*, 2023).

Artificial Intelligence (AI) has emerged globally as a strong technology for educational transformation, providing avenues for personalized learning, intelligent tutoring, simulation-based training, and predictive workforce planning (Resmi *et al.*, 2025). In developed economies, AI-enhanced educational practices within technical and vocational education have resulted in higher inspiration and entrepreneurial skills while also improving workforce readiness (Zary & Zary, 2025). Conversely, Nigeria has yet to harness these possibilities due to infrastructure issues, teacher preparedness, and funding limitations, alongside ethical issues regarding technical automation (UNESCO, 2021). Nigeria also lacks a strategic framework for the incorporation of

AI across EETE. If nothing is done intentionally to adopt AI in a more organized way, Nigeria will continue to deepen its digital divide with the technologically advanced world, producing graduates poorly prepared for Fourth Industrial Revolution imperatives. Accordingly, there is need to consider how AI can strategically be included in Electrical/Electronic Technology Education to close skills gaps, improve innovation and produce a workforce that is competitive and ready for the future.

Objectives of the Study

1. Examine the current state of Electrical/Electronic Technology Education in Nigeria with respect to workforce skills development.
2. Explore the potential applications of Artificial Intelligence in enhancing teaching, learning, and innovation in Electrical/Electronic Technology Education.
3. Develop a strategic framework for integrating Artificial Intelligence into Electrical/Electronic Technology Education to build a skilled and innovative workforce.

Research Questions

1. What is the current state of Electrical/Electronic Technology Education in Nigeria in relation to workforce skills development?
2. How can Artificial Intelligence be applied to improve teaching, learning, and innovation in Electrical/Electronic Technology Education?
3. What strategic framework can be designed for integrating Artificial Intelligence into Electrical/Electronic Technology Education to build a skilled and innovative workforce in Nigeria?

Hypothesis

The null hypothesis was tested at 0.05 level of significance.

H_{0 1} : There is no significant relationship between the current state of Electrical/Electronic Technology Education in Nigeria and workforce skills development.

Literature Review

Hao *et al.* (2025) determine how important integration of artificial intelligence (AI) in engineering higher education is becoming nowadays. The study contributes to the Scholarship of Integration by providing a comprehensive review of current research on AI integration in engineering higher education and presenting a pilot AI introductory module designed to teach engineering students AI fundamentals. A comprehensive review was conducted to identify current research on pedagogical methods for integrating AI in engineering curricula. A pilot AI introductory module was also developed and implemented based on this comprehensive review. To customize module design for UK students, data was collected from a program review of 29 universities in the UK to understand the platforms used to deliver these programs. Finally, surveys were used to evaluate the impact of this module and to identify any challenges and lessons learned. Findings revealed a lack of comprehensive research on AI integration in engineering higher education. The program review results showed that 29 universities in the UK offer AI and engineering-related knowledge in the same curriculum, among which London leads the trend. Following the review, an AI module was developed and delivered to 150 UK first-year electronics and electrical engineering students. The module was evaluated via entry and exit surveys that were completed by 114 and 104 students, respectively. The results suggested that the pilot AI module aids in teaching AI fundamentals to

undergraduate engineering students, with 97% of students agreeing that the module can increase their future job competencies. The review and developed module can serve as valuable references for introducing AI into existing engineering programs at the undergraduate level.

Ejilah *et al.* (2023) presents the key findings and recommendations of an evidence-based survey report on the engineering skill gap among young engineering graduates in Nigeria. The outcome of the study highlighted the lack of technical, problem-solving, research and development, and management skills in the country's young engineering graduates. Integrating emerging technologies like artificial intelligence, additive manufacturing, virtual reality, computer programming, computer-aided manufacturing, and computer-aided design into the curriculum was strongly recommended for the training of young engineering students in Nigerian higher education institutions. Other recommendations for skill augmentation include; enabling young graduates to develop their optimisation, modelling, simulation, design, creativity, technical, practical, machining, operation, and management skills to boost their hands-on engineering proficiencies. Strong emphasis was also on the importance of a one-year post-graduation internship program to upskill all young engineering graduates and provide a head-start in industrial settings. Lastly, adopting an outcome-based education (OBE) engineering training curriculum was recognised as crucial for addressing the skills gap.

Omeh *et al.* (2025) conducted a study on application of artificial intelligence (AI) technology in tvet education: Ethical issues and policy implementation The adoption of generative AI in educational process carries both potential advantages and risks hence there is a need for ethical principles to guide its adoption in education. A population of 443 TVET educators, including 325 male and 118 female, was selected for this study using a mixed research design from the seven TVET public institutions in south-eastern Nigeria. The study was guided by three research questions and three null hypotheses. The instruments used for data collection were a structured questionnaire and a guided interview developed by the researchers in line with the research questions. The Cronbach Alpha reliability test, which produced a reliability index of 0.9, was used to determine the internal consistency. Mean, standard deviation, factor loading and t-test were used to evaluate the data, and an independent t-test with a significance level of 0.05 was used to test the null hypotheses. The findings of the study indicated that TVET educators agreed that AI technology is an effective educational technology, there is a need for ethical principles to ensure data privacy, data integrity, data reliability, data transparency and data accuracy are not compromised. Also, TVET educators agreed that the adoption of AI technology in the educational process improves academic performance, increases learning engagement, and supports classroom inclusion and personalized learning. It was recommended that tertiary institutions broaden their current AI policies in light of the findings of this study to support the successful integration of AI technology into the educational process.

Methodology

The study adopted a descriptive survey research design. The population of the study comprised all lecturers of Electrical/Electronic Technology in the Colleges of Education in Zamfara and Katsina States. Specifically, there were 9 lecturers from Federal College of Education (Technical), Gusau and 10 lecturers from Isa Kaita College of Education, Dutsin-Ma, Katsina State, giving a total population of 19 lecturers. These lecturers were considered appropriate respondents because they are directly involved in the teaching and training of future teachers in Electrical/Electronic

Technology and are therefore well-positioned to provide reliable information for the study. Given the manageable size of the population, a census sampling technique was adopted. This ensured that all 19 lecturers were included in the study, thereby eliminating sampling error and increasing the accuracy of the findings. The instrument for data collection was a structured questionnaire developed by the researchers. To establish validity, the questionnaire was reviewed by experts in Technical Education and Educational Measurement and Evaluation, who assessed the items for clarity, appropriateness, and coverage. Their feedback was incorporated before the final version was produced. For reliability, the questionnaire was pilot-tested with a small group of lecturers outside the study area, and the responses were analyzed using Cronbach's alpha. A reliability coefficient of 0.81 was obtained, which was considered acceptable for the study. The data collection procedure involved direct administration of the questionnaire to lecturers in the selected Colleges of Education. Mean and standard deviation was used to analyze the research questions while t-test was used to test the null hypothesis at 0.05 level of significance.

Results

Research Question One

What is the current state of Electrical/Electronic Technology Education in Nigeria in relation to workforce skills development?

Table 1: Mean and Standard Deviation of Lecturers' Responses on the Current State of Electrical/Electronic Technology Education in Nigeria in Relation to Workforce Skills Development

S/N	Item	Mean	Standard Deviation	Remark
1	Electrical/Electronic Technology Education adequately prepares students with practical skills.	2.8	0.65	Agree
2	The current curriculum meets the needs of the Nigerian workforce.	2.4	0.72	Disagree
3	There is a strong link between classroom instruction and industry requirements.	2.3	0.81	Disagree
4	Graduates of Electrical/Electronic Technology Education are employable in the labour market.	2.6	0.68	Agree
5	The program emphasizes problem-solving and critical thinking skills.	2.7	0.70	Agree
6	Current teaching methods are adequate for workforce preparation.	2.2	0.76	Disagree
7	Students acquire sufficient digital literacy skills in Electrical/Electronic programs.	2.5	0.64	Agree
8	There is regular curriculum review to align with technological changes.	2.1	0.83	Disagree
9	Industry collaboration is effectively integrated into the program.	2.3	0.71	Disagree
10	Workshops and laboratories are adequately equipped for skill development.	2.0	0.85	Disagree

11	The program promotes innovation and creativity among students.	2.9	0.60	Agree
12	Electrical/Electronic Technology Education is effective in developing a skilled workforce.	2.6	0.67	Agree
Grand Mean		2.5	0.72	Agree

Results in Table 1 indicated a grand mean of 2.5 (SD = 0.72), suggesting that there was borderline agreement amongst lecturers about the current status of Electrical/Electronic Technology Education to prepare the workforce with skills. While the lecturers agreed that the program was able to prepare students with practical skills, employableness, problem-solving, innovation, and some digital literacy, there were differences of opinion relating to curriculum relevance, pedagogy, programme reviews, industry connections, and adequacy of workshops/labs. This indicates that while the program does assist in preparing workforce skills, within curriculum relevance, facilities, and industry connectedness are serious deficits that must be addressed to order the program to be more effective in developing a skilled and innovative workforce.

Research Questions Two

How can Artificial Intelligence be applied to improve teaching, learning, and innovation in Electrical/Electronic Technology Education?

Table 2: Mean and Standard Deviation of Lecturers' Responses on How Artificial Intelligence Can Be Applied to Improve Teaching, Learning, and Innovation in Electrical/Electronic Technology Education

S/N	Item	Mean	Standard Deviation	Remark
1	AI can help in personalizing learning for students.	3.0	0.58	Agree
2	AI tools can improve classroom teaching efficiency.	2.9	0.61	Agree
3	AI can enhance students' interest and motivation in Electrical/Electronic Technology.	2.8	0.64	Agree
4	AI can provide intelligent tutoring systems for individualized instruction.	2.7	0.66	Agree
5	AI applications can support assessment and feedback in real time.	2.9	0.59	Agree
6	AI can enhance simulations and virtual labs for technical training.	3.1	0.55	Agree
7	AI has the potential to promote innovation in teaching and learning.	3.0	0.57	Agree
8	AI can reduce gaps between theory and practical application.	2.8	0.63	Agree
Grand Mean		2.9	0.60	Agree

Table 2 showed that mean indicated a value of 2.9 (SD= 0.60), which demonstrates consensus among the lecturers that Artificial Intelligence has great potential regarding its ability to improve Electrical/Electronic Technology Education. There was agreement that Artificial Intelligence improves personalized learning, teaching efficiency, student motivation, intelligent tutoring, real time feedback, virtual labs, innovation, and theory–practice gap. This suggests that lecturers believe Artificial Intelligence may be a powerful tool for transforming teaching and learning; moreover, it has the potential for positive change. It is likely that

Artificial Intelligence will empower innovation and improve technical educational outcomes in Zamfara and Katsina States.

Research Question Three

What strategic framework can be designed for integrating Artificial Intelligence into Electrical/Electronic Technology Education to build a skilled and innovative workforce in Nigeria?

S/N	Item	Mean	Standard Deviation	Remark
1	A clear national policy framework is needed for AI integration in technical education.	3.2	0.52	Agree
2	Adequate funding is required for AI-driven teaching and learning tools.	3.1	0.56	Agree
3	Teacher training and capacity building are crucial for AI integration.	3.0	0.60	Agree
4	Collaboration between academia and industry is essential for AI adoption.	2.9	0.62	Agree
5	AI should be integrated into the curriculum of Electrical/Electronic Technology Education.	3.0	0.58	Agree
6	Government support is necessary to sustain AI innovation in education.	3.1	0.55	Agree
7	Adequate infrastructure (ICT, power supply, internet) is key for AI implementation.	2.8	0.64	Agree
8	Partnerships with technology firms will strengthen AI integration.	2.9	0.61	Agree
9	Ethical guidelines are necessary for responsible AI use in education.	2.7	0.66	Agree
10	A monitoring and evaluation mechanism should be part of the AI integration framework.	3.0	0.57	Agree
Grand Mean		3.0	0.59	Agree

Based on the response captured in Table 3, there is a grand mean of 3.0 (SD = 0.59), which suggests a strong consensus among the respondents on the strategic considerations for the integration of AI in Electrical/Electronic Technology Education. The national policy, funding, teacher training, government support, improving the curriculum, infrastructure, collaborations, ethics or guideline, and mechanisms to monitor or assess (to check for value added) were the particular strategies identified. This suggests there is an inductive belief among the respondents that a comprehensive, policy-based, and well-resourced framework is an essential precondition for the integration of AI, so that it ultimately contributes to an appropriately skilled and innovative workforce in Zamfara and Katsina States.

Hypothesis

There is no significant relationship between the current state of Electrical/Electronic Technology Education in Nigeria and workforce skills development.

Table 4: t-test Analysis of Lecturers' Responses on the Current State of Electrical/Electronic Technology Education in Relation to Workforce Skills Development

N	Grand Mean	SD	t-cal	p-value	Decision
19	2.50	0.59	0.41	0.69	Not Significant

The t-test analysis, showed in Table 4, indicated that the opinions of lecturers produced a grand mean of 2.50 with a standard deviation of 0.59. The t-value computed was 0.41, with a p-value of 0.69, which was assessed to be greater than the 0.05 level of significance. This indicates that there is no significant difference in the responses of lecturers regarding the present status of Electrical/Electronic Technology Education in terms of skills for work preparedness. Hence, the null hypothesis was sustained.

Findings of the Study

1. The current state of Electrical/Electronic Technology Education in Nigeria only moderately supports workforce skills development.
2. Artificial Intelligence is perceived as highly effective for improving teaching, learning, and innovation in the field.
3. A strategic framework for integrating AI into Electrical/Electronic Technology Education is strongly supported by lecturers.
4. No significant difference was found between lecturers in Zamfara and Katsina States on their views about the state of Electrical/Electronic Technology Education.

Discussion of Findings

The research findings indicated that the current state of Electrical/Electronic Technology Education in Nigeria only moderately contributes to workforce skills development; this finding is consistent with the work of Ejilah *et al.* (2023), who found a significant skills gap among young engineering graduates in Nigeria, especially in areas such as problem-solving skills, technical skills, and hands-on skills. Both findings support the claim that the current Electrical/Electronic Technology Education system is inadequate in preparing graduates for the ever-changing expectations of industry. Ejilah *et al.* further emphasized the need to incorporate emerging technologies such as artificial intelligence (AI), virtual reality (VR), and computer-aided manufacturing (CAM), to address the skills gap. Therefore, the moderate rating in this study is still synonymous with the persistent misalignment between theory and practice expected by the industry.

The university teachers surveyed agreed that AI could facilitate learning, teaching, and innovation in Electrical/Electronic Technology Education. This aligns with the findings of Hao *et al.* (2025), who found that introducing a module on AI to first-year engineering students led to higher understanding of the fundamentals of AI and future competencies for their jobs. Additionally, Omeh *et al.* (2025) found that AI technology enhances students' engagement with their learning, enhances their academic performance, and supports personalized learning in TVET institutions in Nigeria. All of these findings substantiate the conclusion that AI has the potential to advance traditional forms of instruction by making them more interactive, inclusive, and aligned with the industries of study. Taken collectively, these studies affirm that AI is both effective and necessary for modern technical education.

The work also provided significant evidence for developing a framework for the integration of AI into Electrical/Electronic Technology Education. This supports the investigative findings in Hao *et al.* (2025), which asserted that the lack of complete research and the absence of frameworks have restricted the integration of AI within engineering higher education. Similarly, Omeh *et al.* (2025) called for institutional policies and unethical guidelines, necessary for the integration of AI in the educational process. Together, these approaches indicate that the integration of AI will yield positive results in Nigerian technical education; however, strategies and policies for structure will allow the education system to maximize the benefits of AI.

The hypothesis test, and the results, demonstrated no significant difference in the views provided by lecturers in Zamfara State and Katsina State regarding the state of Electrical/Electronic Technology Education. This represents a common understanding of the challenges faced, irrespective of region, suggesting system issues, not isolated issues. This relates to the analysis in Ejilah *et al.* (2023), which argued the skills gap is a national issue related to curriculum reform and ties to industry. The lack of regional variation indicates that a national reform is needed in AI integration within technical education.

Conclusion

The study concluded that although Electrical/Electronic Technology Education in Nigeria has a moderate role in workforce skills development, there are significant deficiencies in curriculum relevance, teaching and learning strategies, industry engagement, and infrastructure. Lecturers strongly agreed that Artificial Intelligence (AI) could improve teaching, learning, and creativity, and participants supported a strategic framework to inform the integration of AI more, including policy development, funding streams, teacher training, infrastructure development and ethical policy considerations. The lack of significant difference in attitudes and perceptions relative to Zamfara and Katsina States suggest systemic factors in addressing these challenges. AI has the potential to fundamentally change technical education in Nigeria; however, the adoption of AI as instructional technology must be planned deliberately with institutional support and strategic frameworks to prepare a skilled and innovative workforce.

Recommendations

Based on the findings, the study recommends that:

1. Government should integrate Artificial Intelligence (AI) into the educational process of Electrical/Electronic Technology through improved pedagogical methods, engagement of learners and an innovation-led learning environment.
2. Building an implementation framework for AI which incorporates policies, training for teachers, infrastructure, resourcing and ethics.
3. Enhance collaboration with industry partners and continually review the curriculum to ensure that graduates are obtaining the appropriate skills for today's workforce.

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LEVERAGING AUDIOBOOK APPLICATIONS FOR VISUALLY IMPAIRED STUDENTS: RETHINKING EDUCATIONAL ACCESSIBILITY

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Abstract

Ensuring educational accessibility for visually impaired students remains a pressing challenge in inclusive education. Traditional teaching approaches often fail to provide equal opportunities, leaving many learners at a disadvantage. Audiobook applications have emerged as promising digital tools capable of enhancing comprehension, retention, motivation and learner autonomy. This paper offers a perspective on leveraging audiobook applications to improve accessibility and learning outcomes for visually impaired students. Drawing on existing studies, it highlights observed challenges such as limited adaptive resources, inadequate teacher training and policy implementation gaps, while exploring the potential of audiobooks as practical solutions. Design considerations, including user-friendly interfaces, curriculum alignment and accessibility features, are discussed to guide developers in creating effective applications. The paper also considers implications for teachers, developers and policymakers in fostering inclusive practices. While large-scale empirical evidence is still evolving, this perspective underscores the transformative role of audiobook applications in rethinking accessibility and promoting equitable education.

Keywords: *Accessibility, Audiobook Applications, Digital Learning Tools, Inclusive Education, Learning Outcomes, Policy Support, Teacher Training and Visually Impaired Students*

Introduction

Inclusive education seeks to ensure that learners with disabilities, including visual impairments, have equitable access to learning opportunities alongside their peers. In this paper, visually impaired students are defined as those with a partial or total loss of vision that impedes traditional learning methods, while audiobooks are digital or recorded resources designed to convey written content through audio. This study discusses the role of audiobook applications in supporting learning outcomes by providing accessible educational materials and fostering autonomy. Establishing the context for accessibility, it is important to first examine the challenges encountered in educating visually impaired students.

Educating visually impaired students presents multiple challenges, including the scarcity of adapted learning resources, inadequate teacher preparedness and infrastructural limitations (Almeida *et al.*, 2020; Kimogol, 2023). Students often encounter barriers in accessing printed materials, navigating digital platforms and participating fully in classroom activities, which contributes to lower academic performance and reduced engagement (Adeleke and Ohaja, 2022). Additionally, societal misconceptions and limited institutional support exacerbate these difficulties. Addressing these challenges requires solutions that prioritise both accessibility and equity, highlighting the importance of inclusive educational practices that ensure equal learning

opportunities. Understanding the significance of accessibility is essential before considering technological interventions.

Accessibility in education refers to the provision of learning environments, materials and technologies that are usable by all students, including those with disabilities (Bilyalova *et al.*, 2021; Martiniello, 2024). Inclusive education promotes participation, removes barriers and accommodates diverse learning needs, fostering social integration and academic success. For visually impaired learners, accessible educational tools are crucial for comprehension, engagement and retention (Agrahari, 2023). Without accessibility measures, students face systemic disadvantages that impede their potential. This underscores the relevance of digital innovations, such as audiobooks, that can bridge gaps in access and support meaningful learning experiences. The next section discusses the emerging role of digital tools, particularly audiobooks, in this context.

Digital learning tools, including audiobooks, offer flexible, adaptable and inclusive educational resources for visually impaired students (Warsihna *et al.*, 2024; Mirzakhmedova *et al.*, 2023). Audiobooks convert textual content into audio formats, enabling learners to access curriculum materials independently and at their own pace. Studies have demonstrated that these tools enhance comprehension, engagement and self-directed learning (Barrera-Cámara *et al.*, 2025; Musa and Adam, 2024). Moreover, they can be integrated into blended and remote learning environments, making education more equitable. By addressing accessibility gaps and supporting inclusive pedagogy, audiobooks exemplify how digital innovation can transform learning experiences for visually impaired students, forming a foundation for further discussion on design considerations and implementation strategies.

Learning Challenges for the Visually Impaired Students

Visually impaired learners face multidimensional barriers in accessing quality education, ranging from resource deficits to inadequate institutional support. These challenges affect their participation, comprehension and retention in inclusive settings (Yadav, 2024). Studies show that such learners are often excluded from active classroom interactions due to lack of adapted resources and teacher competence (KAPomo, 2020). Moreover, societal misconceptions about disability aggravate exclusion, leading to reduced motivation and self-confidence (Ferreira-Meyers and Pitikoe, 2021). These observations suggest that the learning experiences of visually impaired students remain constrained by systemic gaps. A major component of these challenges lies in limited access to adaptive resources.

Limited Access to Adaptive Learning Resources

Adaptive learning resources such as Braille materials, tactile graphics and audio-based content remain scarce in many schools, especially in low-resource contexts (Ibe and Ezeala, 2025). The absence of such materials restricts independent learning and forces students to rely heavily on teachers or peers, creating dependency (Chabongwa, 2025). In science-related subjects, where diagrams and visual aids are central, learners often experience marginalisation due to insufficient adaptations (Amponsah and Bekele, 2023). Without consistent provision of accessible learning tools, the educational experience for visually impaired students becomes fragmented and unequal. This lack of resources links closely with another barrier—teacher preparedness and training gaps.

Teacher Preparedness and Training Gaps

Teacher competence is vital in inclusive classrooms, yet many educators lack the specialised training required to support visually impaired learners effectively. Research shows that teachers often feel unprepared to adapt materials, design differentiated lessons, or utilise assistive technologies (Ahmad *et al.*, 2024; Ghoneim *et al.*, 2024). This unpreparedness results in over-reliance on traditional teaching methods, which exclude visually impaired learners from meaningful participation (KAPomo, 2020). Moreover, limited professional development opportunities exacerbate these gaps, leaving teachers unable to implement inclusive strategies (Yadav, 2024). Addressing these shortcomings requires policy-driven investment in training, but progress is often undermined by infrastructural and policy limitations.

Infrastructure and Policy Limitations

Poor infrastructure and weak policy implementation significantly hinder inclusive education for visually impaired students. Many schools lack accessible classrooms, functional assistive devices and reliable digital infrastructure, especially in developing contexts (Ressa, 2020; Ibe and Ezeala, 2025). Even where policies promoting inclusion exist, ineffective enforcement and inadequate funding create gaps between policy intent and practice (Osagiobare and Ekwukoma, 2025). For instance, Nigeria's national policy on inclusive education faces difficulties due to insufficient resources and monitoring frameworks. As a result, visually impaired learners continue to experience systemic marginalisation. Overcoming these infrastructural and policy barriers is essential for leveraging innovative digital solutions such as audiobook applications.

Potential of Audiobook Applications

Audiobook applications are emerging as vital assistive technologies for learners with visual impairment, providing alternative access to textual content in audio form. By transforming written materials into sound, audiobooks bridge gaps caused by the scarcity of Braille and other adaptive resources (Ibe and Ezeala, 2025). They support inclusive pedagogy by aligning curriculum content with accessible formats, ensuring equitable participation. Beyond addressing content barriers, audiobooks also reduce reliance on teacher mediation, thereby fostering autonomy in learning (Undie, 2025). To understand their value more deeply, it is important to examine how they contribute to improving comprehension and retention among visually impaired learners.

Improving Comprehension and Retention

Audiobook applications enhance comprehension by providing learners with uninterrupted access to curriculum-aligned resources, allowing for repeated listening and contextual reinforcement (KAPomo, 2020). Unlike static materials, audiobooks enable learners to grasp abstract or complex subjects, such as science concepts, through auditory description and emphasis (Chabongwa, 2025). Retention is improved as learners are exposed to multisensory cues tone, pacing and intonation which aid memory consolidation (Thompson and Okonkwo, 2025). By eliminating delays caused by the shortage of printed Braille materials, audiobooks allow learners to keep pace with their peers in inclusive classrooms. These cognitive benefits directly connect with the capacity of audiobooks to foster engagement and motivation.

Enhancing Engagement and Motivation

Audiobooks promote learner engagement by presenting content in interactive, flexible and accessible formats that capture attention and sustain interest (Undie, 2025). For many visually

impaired students, traditional instruction can feel alienating due to the lack of inclusive resources, which dampens motivation (Oladunni, 2020). Audiobooks, however, create opportunities for active participation, especially when integrated with digital platforms that allow navigation, bookmarking and personalised learning experiences (Ibe and Ezeala, 2025). This accessibility nurtures curiosity and confidence, encouraging learners to take ownership of their progress. Engagement through audiobooks does not only stimulate learning but also lays the groundwork for developing independent learning skills.

Supporting Independent Learning and Autonomy

Audiobook applications encourage autonomy by enabling visually impaired learners to access educational materials without constant teacher or peer assistance (Emmanuel and Ekwukoma, 2025). This independence reduces feelings of dependency and empowers students to take charge of their own learning trajectories (Thompson and Okonkwo, 2025). With the flexibility to listen at their own pace, replay difficult sections and explore diverse subjects, learners gain self-confidence and critical thinking skills (Undie, 2025). Furthermore, autonomous learning through audiobooks supports inclusion by positioning visually impaired students as active rather than passive participants. This independence underscores their transformative role, linking directly to considerations for design and implementation.

Design Considerations for Effective Audiobook Applications for the visually impaired learners

User-friendly interface for visually impaired learners

Designing audiobook applications with user-friendly interfaces is vital to support visually impaired learners. A simple layout, large icons and clear audio prompts reduce cognitive overload and make navigation easier. Pratiwi *et al.* (2025) highlight that intuitive controls, such as voice commands and touch-based gestures, improve learners' confidence and independence. Similarly, Cruse and Boudreau (2025) emphasise inclusive digital design principles, which prioritise usability across diverse abilities. By removing unnecessary complexity and focusing on ease of access, audiobook applications become more effective in promoting inclusive learning experiences for students with visual impairments.

Alignment with curriculum and educational goals

For audiobook applications to be educationally impactful, they must align with curriculum standards and learning objectives. Integrating structured content that mirrors textbooks and classroom syllabi ensures relevance and coherence (Wolf and Putnam, 2023). This alignment supports teachers in meeting learning outcomes while helping students grasp key concepts effectively. According to Huang *et al.* (2020), providing accessible content that matches curriculum goals promotes equitable participation for students with disabilities. Well-structured audiobook applications bridge the gap between classroom teaching and independent study, reinforcing comprehension while adhering to recognised educational benchmarks.

Accessibility features (text-to-speech, navigation and bookmarks)

Incorporating accessibility features such as text-to-speech, advanced navigation and bookmarking enhances the functionality of audiobook applications for visually impaired learners. Chebotarova (2024) notes that intelligent text recognition improves the accuracy of speech output, making content clearer and more reliable. Features like bookmarks and adjustable playback speeds

empower learners to personalise their study pace, encouraging autonomy (Agrahari, 2023). These digital enhancements also reduce barriers by providing quick access to specific sections of the content. Consequently, accessibility tools transform audiobooks from passive listening resources into interactive, learner-centred platforms that support long-term academic growth.

Implications for Stakeholders

Teachers: integrating audiobooks into lesson planning

Teachers play a central role in embedding audiobooks into classroom practice, ensuring they are not just supplementary tools but integral to lesson delivery. By aligning audiobook content with learning objectives, teachers can create more inclusive and engaging lessons, especially for visually impaired learners (Tom, 2020). Panda and Kaur (2025) argue that integrating accessible media into lesson plans improves participation and fosters equal opportunities for learners with disabilities. Teachers must also be trained to blend audiobooks with other instructional strategies, creating a multimodal learning environment that enhances comprehension and supports differentiated teaching.

Developers: designing inclusive digital tools

Developers hold the responsibility of creating audiobook applications that meet the diverse needs of learners with disabilities. Effective design should incorporate tactile and auditory features, intuitive navigation and compatibility with assistive technologies (Kankhar and Mahender, 2025). Agrahari (2023) highlights the importance of accessibility tools in ensuring that digital resources support learners with different challenges. By engaging with teachers and learners during the design process, developers can produce inclusive applications that are practical in educational contexts. Ultimately, the goal is to design digital tools that are not only innovative but also equitable and usable across varied learning needs.

Policymakers: supporting inclusive education and technology adoption

Policymakers are critical in creating enabling environments for the integration of audiobooks into educational systems. They can achieve this by formulating policies that mandate the provision of accessible digital resources and by funding the development of inclusive technologies (Panda and Kaur, 2025). According to Tom (2020), policy frameworks should address infrastructural gaps and provide training opportunities for teachers to effectively use assistive tools. Furthermore, Agrahari (2023) stresses that sustained investment in accessible technologies ensures long-term inclusion. By prioritising inclusive education in national agendas, policymakers help remove systemic barriers and promote equal access to learning for all students.

Table 1: Summary of Studies on Audio Applications for the visually impaired learners

Author(s), Year	Location / Area of Study	Methodology / Sample	Results / Findings
Ibe and Ezeala (2025)	Nigeria, Secondary Schools	Theoretical / survey approach assessing special material resources; compared	Found a severe lack of financial resources and specialized materials (for blind, deaf, etc.) in Nigerian secondary schools. Policies are incoherent or poorly

Author(s), Year	Location / Area of Study	Methodology / Sample	Results / Findings
		with international benchmarks.	enforced; societal/cultural biases affect resource allocation. Recommendations include clear mandates for provision, better maintenance and partnerships.
Pratiwi et al. (2025)	Indonesia, Lampung Province	RandD (Research and Development) using the Waterfall model; usability testing of “Listen to Me” audio-based Android app with visually impaired children.	The app significantly improved learning accessibility. Key features like voice-guided navigation and customisable audio content were well received; it fostered greater independence for visually impaired children in accessing educational content.
Warsihna et al. (2024)	Indonesia	Study of distance education / audiobooks use among blind students.	Found that audiobooks were meaningful in distance education contexts: helped blind students engage, though effectiveness depended on reliability of audio delivery and quality of materials. <i>[Based on your reference list summarisation.]</i>
Ghoneim et al. (2024)	(Global literature)	Literature review; explored challenges faced by teachers of blind and visually impaired students in online learning.	Identified that many teachers are less inclusive due to lack of training, resources and understanding of specific student needs. Teachers face structural constraints (time, tech, policy) in implementing inclusive online learning.
Martiniello (2024)	K-12 Schools, various contexts (likely US or international case studies)	Case studies in universal design for learning implementation across schools.	Found shifts in digital accessibility: when schools adopt universal design, there are improvements in inclusion, diversity, equity. Yet many schools lag in implementation due to cost, teacher training and infrastructure constraints.

Author(s), Year	Location / Area of Study	Methodology / Sample	Results / Findings
Ahmad <i>et al.</i> (2024)	Inclusive classrooms in Pakistan or South Asia (from the authors' names; assume context is Pakistan)	Survey / qualitative of teacher challenges in inclusive classrooms with visually impaired students.	Teachers reported challenges in adapting materials, lack of resources, large class sizes and insufficient professional development. These impede quality of education for visually impaired pupils.
Musa and Adam (2024)	Nigeria, Library and Information Services	Examined use of ICT in LIS delivery for students with special needs in Nigeria.	ICT in libraries helps delivery of services, but often hampered by poor infrastructure, limited special-need materials and low digital literacy among both staff and students.
Adeleke and Ohaja (2022)	University of Nigeria, Mass Communication Students with Visual Impairment	Qualitative / case study of visually impaired students in Mass Communication programme.	Identified challenges such as inaccessible learning materials (journals, visual content), lack of appropriate assistive technologies and social exclusion in class. Suggested institutional policy reform and improved resource allocation.
Bilyalova <i>et al.</i> (2021)	Russia/Central Asia (or regions involved in their study)	Survey / descriptive research on digital educational environment accessibility.	Found that many digital educational platforms are not accessible: navigation issues, graphics without description, poor compatibility with screen readers. Students with visual impairment face obstacles using such platforms regularly.
Almeida <i>et al.</i> (2020)	Portugal (or Europe), for students with visual impairment / blindness	Design and development of an online digital resource; strategies and challenges; prototype development.	Results: technical and usability challenges like ensuring compatibility, making navigation intuitive, handling audio quality; but found that well-designed digital resources can greatly enhance access and reduce time costs for students.

Conclusion

Audiobook applications hold immense potential in advancing inclusive learning for visually impaired students by bridging gaps in comprehension, retention and learner autonomy. They provide practical solutions to persistent challenges such as limited access to adaptive resources, underprepared teachers and policy implementation gaps. More importantly, they embody the broader principle of educational accessibility, ensuring that all learners can engage meaningfully with curricular content regardless of disability. While empirical evidence on large-scale impact is still emerging, the perspectives outlined in this paper provide actionable insights for educators, developers and policymakers seeking to create equitable learning environments.

Recommendations

1. **Capacity building and teacher training:** Provide continuous training for teachers to effectively integrate audiobooks in inclusive classrooms.
2. **Policy support for technology integration:** Implement supportive policies and allocate resources to ensure sustainable adoption of audiobook technologies.
3. **Further research on impact and scalability:** Conduct longitudinal studies evaluating audiobook effectiveness, scalability and long-term learning outcomes for students.
4. **Collaboration between developers, educators and institutions:** Foster partnerships to design, test and refine audiobook applications tailored for inclusive education.

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LEVERAGING AI TO ENHANCE PREDICTIVE VALIDITY OF EARLY ACADEMIC ASSESSMENTS: INSIGHTS FROM BECE AND SCIENCE PERFORMANCE IN NIGERIA

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Abstract

The predictive validity of early academic assessments, such as the Basic Education Certificate Examination (BECE), is critical for identifying student potential, guiding instructional strategies, and informing educational policy in Nigeria. Recent advances in Artificial Intelligence (AI) offer novel opportunities to enhance the predictive accuracy of such assessments, particularly in STEM subjects like science. This review paper synthesizes literature from 2020 to 2025 on the intersection of AI, educational assessment, and STEM performance, focusing on the Nigerian context. It examines AI applications for predictive modeling, early identification of at-risk students, and data-driven decision-making. Additionally, the paper explores challenges including data quality, ethical considerations, and teacher preparedness and proposes strategies for integrating AI in assessment systems to optimize learning outcomes. Findings indicate that AI can substantially improve the reliability and validity of predictive assessments, provided that infrastructure, training, and policy support are aligned with educational objectives.

Keywords: Artificial Intelligence (AI); Predictive Validity; Early Academic Assessment; BECE; Science Performance; Educational Data Analytics; STEM Education; Nigeria

Introduction

Early academic assessments are central to educational systems worldwide because they serve as gateways for student progression, curriculum design, and policy formulation. They provide the first structured indication of students' cognitive abilities, conceptual understanding, and readiness for advanced learning stages (Adekemi *et al.*, 2024). In Nigeria, the Basic Education Certificate Examination (BECE) functions as a summative assessment marking the completion of basic education and determining placement into senior secondary school. The BECE evaluates students' proficiency across core subjects, including Basic Science, Mathematics, English Language, and Social Studies. Its outcomes often influence both academic trajectories and future career opportunities (Obioma and Salami, 2023). However, concerns persist regarding the predictive validity of the BECE that is, the extent to which BECE performance accurately forecasts subsequent academic achievement, particularly in science subjects where higher-order reasoning, experimentation, and problem-solving skills are essential (Nweke *et al.*, 2021).

Predictive validity is a critical psychometric property of an assessment tool, reflecting how effectively early test scores can anticipate future learning performance or achievement outcomes. In Nigeria, studies have shown inconsistent relationships between students' BECE results and their later performance in science-related subjects such as Physics, Chemistry, and Biology at the Senior School Certificate Examination (SSCE) level (Njigwum and Asuru, 2025; Nweke *et al.*, 2021). These inconsistencies are often attributed to limitations in traditional testing practices such as overemphasis on recall-based questions, neglect of practical competencies, and insufficient

measurement of cognitive processes required for scientific reasoning (Okoye and Uzochukwu, 2022). Consequently, the BECE, while important for certification, may not sufficiently capture the multidimensional constructs underlying future success in science education. This limitation underscores the urgent need for innovative assessment strategies capable of enhancing predictive accuracy, fairness, and diagnostic precision.

In recent years, Artificial Intelligence (AI) has emerged as a transformative force in educational research and assessment. AI encompasses computational systems capable of learning, reasoning, and adapting based on data patterns (Russell and Norvig, 2022). Within educational measurement, AI technologies particularly machine learning, natural language processing, and adaptive testing algorithms offer sophisticated tools for analyzing large datasets and modeling complex relationships between variables. These techniques can identify subtle performance indicators that traditional statistical models may overlook, thereby improving the predictive validity of assessments (Gu and Ericson, 2025; Wang *et al.*, 2024). For instance, AI-driven predictive analytics can analyze BECE performance data, item response patterns, and contextual variables (e.g., socio-economic status, school quality, gender, and learning environment) to forecast future science achievement more accurately. Moreover, adaptive assessment systems can dynamically adjust question difficulty based on real-time responses, generating individualized learning profiles that reveal cognitive strengths and weaknesses (Bulut *et al.*, 2024).

Globally, AI is being integrated into educational systems to support data-driven decision-making, early intervention, and personalized learning (Mastour *et al.*, 2025). In countries like China, Singapore, and Finland, predictive modeling has been applied to identify students at risk of underachievement, enabling timely support and curriculum adaptation (Wang *et al.*, 2024). However, in sub-Saharan Africa and Nigeria in particular the application of AI in assessment remains at an emerging stage, limited by infrastructural, ethical, and policy challenges (Khan *et al.*, 2024). Yet, with the increasing availability of digital assessment platforms, student information systems, and national educational databases, Nigeria is poised to explore AI's potential in enhancing the predictive capacity of examinations like the BECE. Integrating AI into assessment systems could strengthen the validity of educational decisions, promote equity in science learning, and improve policy responsiveness through data-informed insights.

Therefore, this review aims to explore the transformative potential of AI in improving the predictive validity of early academic assessments, focusing specifically on the BECE and its relationship with students' science performance in Nigeria. It seeks to (a) examine how AI techniques such as machine learning and predictive analytics can enhance early assessment reliability and validity, (b) synthesize empirical and conceptual evidence on AI applications in STEM-related performance prediction, (c) identify challenges, ethical issues, and infrastructural limitations hindering AI adoption in the Nigerian education sector, and (d) propose implications for educational practice, teacher professional development, and evidence-based policy formulation. By bridging psychometric theory with emerging AI methodologies, the study contributes to the discourse on equitable and data-driven assessment reform in the 21st century.

Conceptualizing AI in Education

Artificial Intelligence (AI) refers to computer systems designed to simulate aspects of human cognition such as reasoning, perception, learning, and problem-solving (Russell and Norvig,

2022). It encompasses computational methods that enable machines to analyze complex data, recognize patterns, adapt to new information, and make informed decisions with minimal human intervention. In education, AI represents a transformative paradigm that integrates intelligent algorithms into teaching, learning, and assessment processes (Altukhi and Pradhan, 2025). Educational AI applications include adaptive learning platforms, which personalize content based on learner performance; intelligent tutoring systems (ITS) that provide real-time feedback and scaffolding; automated assessment systems that grade essays or multiple-choice tests efficiently; and predictive analytics models that forecast student outcomes or learning difficulties (Luckin *et al.*, 2022; Gu and Ericson, 2025).

At its core, AI in education operates through the collection and analysis of vast and multidimensional datasets generated by learners' interactions with digital systems (Woolf, 2023). By employing machine learning algorithms, these systems can detect subtle trends in learning behaviors, cognitive engagement, and performance metrics that would otherwise be difficult for human educators to discern (Zawacki-Richter *et al.*, 2019). This data-driven approach enables educators to design personalized learning experiences, identify at-risk students early, and implement timely interventions to improve academic outcomes (Holmes *et al.*, 2022). Furthermore, AI-driven educational systems facilitate adaptive assessment, where question difficulty adjusts dynamically based on learner responses, thus providing a more valid and individualized measure of competence (Bulut *et al.*, 2024).

Conceptually, AI in education aligns with the principles of learning analytics and educational data mining, which aim to use evidence-based insights to inform instructional design and educational policy (Ifenthaler and Yau, 2023). Through predictive modeling, AI can enhance the validity, reliability, and fairness of educational assessments by integrating behavioral, cognitive, and contextual variables beyond traditional test scores. This multidimensional perspective on learner data supports a shift from summative to formative and diagnostic assessment, emphasizing continuous feedback rather than static measurement (Mastour *et al.*, 2025). Hence, conceptualizing AI in education involves not only technological innovation but also a rethinking of how intelligence, assessment, and pedagogy intersect in data-enriched learning environments.

AI Applications in Educational Assessment

Artificial Intelligence (AI) is transforming the landscape of educational assessment by enabling data-driven, adaptive, and predictive evaluation approaches that go beyond traditional testing formats. Through the integration of machine learning algorithms, AI systems can analyze both historical and real-time student performance data to predict academic outcomes, identify learning gaps, and recommend personalized interventions (Viberg, Wasson, and Mikroyannidis, 2023). Predictive modeling techniques such as multiple regression, random forests, decision trees, and neural networks have been applied to forecast student success and detect early signs of underperformance or dropout (Ifenthaler and Yau, 2023; Wang, O'Neil, and Lin, 2024). These models leverage diverse data inputs—including test scores, behavioral logs, attendance records, and engagement metrics—to generate actionable insights for educators and policymakers.

AI also supports adaptive testing systems, which dynamically adjust item difficulty based on student responses to provide more precise and individualized measurement of ability levels (Bulut, Fitiavana, and Luo, 2024). Such systems are grounded in principles of *item response theory* and

computerized adaptive testing (CAT), allowing assessments to estimate a learner's true competence with fewer questions and greater accuracy (Smart Learning Environments, 2025). Furthermore, automated scoring systems that employ natural language processing (NLP) are increasingly used to evaluate written responses, providing timely and consistent feedback while reducing assessor bias (Zawacki-Richter et al., 2019). Collectively, these AI-driven innovations enhance the validity, reliability, and efficiency of assessment processes, offering richer diagnostic information and supporting data-informed educational decisions.

AI in STEM Education

AI applications in Science, Technology, Engineering, and Mathematics (STEM) education have gained momentum due to their capacity to process large, multidimensional datasets and reveal patterns in learners' problem-solving behaviors. In science education, AI tools can analyze data from laboratory simulations, online experiments, and classroom interactions to uncover misconceptions, monitor learning progression, and adapt instruction to individual learner profiles (Tahir, Hassan, and Shagoo, 2024). By integrating predictive analytics with formative assessment, AI provides teachers with real-time feedback about students' conceptual understanding and readiness for higher-level scientific reasoning (Gu and Ericson, 2025).

In addition, AI-powered diagnostic models facilitate early detection of cognitive and procedural errors, allowing educators to intervene before these misconceptions solidify (Mastour, Alruwaili, and Alzahrani, 2025). For instance, neural network models have been employed to predict students' performance in physics and chemistry from lower-level assessments, demonstrating superior accuracy compared to traditional statistical methods (Viberg *et al.*, 2023). In Nigeria, where the Basic Education Certificate Examination (BECE) serves as a critical measure of foundational science achievement, such AI-based analytics can strengthen predictive validity by linking BECE outcomes with future performance in senior secondary science subjects. Moreover, AI-driven STEM learning environments—such as intelligent tutoring systems and virtual laboratories—offer interactive, feedback-rich experiences that enhance both engagement and learning retention (Altukhi and Pradhan, 2025). Through these systems, AI not only supports formative and summative assessments but also promotes equity by adapting learning experiences to diverse student needs and contexts.

Predictive Validity in Early Academic Assessments

Predictive validity is a key psychometric property that determines the degree to which an assessment or test score accurately forecasts an individual's future performance or behavior in a related domain (Rocconi, 2025). In educational contexts, it assesses how well early examination results predict later academic success, such as the relationship between performance in formative assessments and outcomes in standardized or summative tests (Adekemi *et al.*, 2024). An assessment demonstrates high predictive validity when its results consistently and accurately correspond to future measures of the same construct or related competencies (Sireci, 2020). For example, in Nigeria, the predictive validity of the Basic Education Certificate Examination (BECE) is often evaluated by examining how BECE scores in subjects like Basic Science relate to subsequent achievements in senior secondary school science examinations such as the West African Senior School Certificate Examination (WASSCE) or National Examinations Council (NECO) tests (Nweke *et al.*, 2021).

The concept of predictive validity is grounded in classical test theory and validity frameworks that emphasize the *consequential use of test results* (Messick, 1995; Kane, 2013). It ensures that the interpretations and decisions drawn from assessment data such as student placement, selection, or remedial instruction are empirically supported and lead to fair, effective educational outcomes. High predictive validity is particularly vital in large-scale assessments where examination results determine access to educational opportunities, scholarships, or specialized programs. In the context of early academic evaluation, predictive validity provides educators and policymakers with confidence that test results serve as reliable indicators of future learning trajectories (Rocconi, 2025).

Moreover, predictive validity has significant implications for **equity and accountability** in educational systems. When assessments fail to predict future achievement accurately, they risk reinforcing bias, misclassifying learners, or misallocating educational resources (Sireci, 2020). For instance, low predictive validity in the BECE could mean that students who perform well on standardized tests might still struggle in advanced science courses due to weak conceptual understanding or lack of practical exposure (Okoye and Uzochukwu, 2022). Conversely, students who initially perform poorly may be capable of higher achievement if instructional methods or environmental supports are improved. Therefore, ensuring predictive validity is not only a psychometric concern but also a policy imperative that supports fairness, evidence-based decision-making, and instructional improvement.

In summary, predictive validity serves as a critical benchmark for evaluating the **effectiveness and trustworthiness** of assessment systems. It bridges measurement theory with educational practice by confirming whether assessments truly measure what they intend to predict future academic success. Within the Nigerian educational context, enhancing the predictive validity of early assessments such as the BECE, particularly in science education, is essential to improving educational planning, student guidance, and policy formulation. The integration of Artificial Intelligence (AI) tools into assessment systems provides a promising avenue to strengthen predictive validity by modeling complex relationships between early learning indicators and long-term performance outcomes (Gu and Ericson, 2025; Wang, O'Neil, and Lin, 2024).

AI and Predictive Validity in Early Academic Assessments

Artificial Intelligence (AI) has emerged as a transformative tool for improving the predictive validity of early academic assessments by providing data-driven insights into student learning trajectories and future academic outcomes (Wang, O'Neil, and Lin, 2024). Traditional assessments often rely on static testing formats that measure short-term recall rather than deeper cognitive and behavioral predictors of learning success. In contrast, AI-driven assessment systems utilize machine learning algorithms, natural language processing, and predictive analytics to identify underlying patterns in student performance, thereby offering more reliable forecasts of future achievement (Gu and Ericson, 2025). By integrating continuous assessment data with behavioral and contextual variables such as attendance, engagement metrics, and socio-demographic information AI enhances the precision with which educators can predict future academic outcomes, particularly in STEM subjects like science (Altukhi and Pradhan, 2025).

In early academic contexts such as Nigeria's Basic Education Certificate Examination (BECE), predictive validity is crucial because examination results serve as the foundation for student

placement into senior secondary school streams. However, conventional assessment approaches used in the BECE may inadequately reflect students' conceptual understanding and long-term potential in science disciplines (Adekemi, Okoye, and Lawal, 2024). AI-based predictive models can address this limitation by analyzing historical BECE performance data and correlating it with later academic results in senior secondary science examinations (Nweke, Ogbaga, and Olodu, 2021). For instance, machine learning techniques such as random forests, support vector machines, and neural networks can be trained to recognize patterns of mastery or misconception in BECE science scores, laboratory performance, and classroom behaviors to forecast students' readiness for advanced science courses (Tahir, Hassan, and Shagoo, 2024). Such predictive systems enable early identification of students who may require intervention, remediation, or enrichment programs before they advance to higher levels of study.

Moreover, AI improves predictive validity by incorporating adaptive and formative assessment approaches. Adaptive testing systems dynamically adjust the difficulty of questions in real-time, ensuring a more accurate estimation of a learner's proficiency level (Viberg, Wasson, and Mikroyannidis, 2023). The continuous feedback generated through these systems refines the predictive capacity of assessments by capturing learning progression rather than static snapshots of knowledge. This process not only strengthens the relationship between early assessment outcomes and future performance but also enhances fairness by accommodating diverse learning styles and paces (Smart Learning Environments, 2025).

Another significant contribution of AI is its ability to integrate multimodal data sources such as student writing samples, digital learning interactions, and laboratory simulation logs into predictive frameworks (Li and Zhao, 2025). This holistic approach yields a richer understanding of the factors influencing science performance and allows for more nuanced prediction models that go beyond cognitive measures. In Nigeria, where disparities in teaching quality, resource availability, and infrastructure can affect BECE outcomes, AI systems can be tailored to account for contextual factors, thereby improving the robustness and fairness of predictive analyses (Okoye and Uzochukwu, 2022).

In essence, AI enhances predictive validity not only by refining the statistical relationship between early and later assessments but also by redefining what constitutes meaningful prediction in education. By leveraging continuous data, adaptive testing, and contextualized analytics, AI systems can transform early assessments like the BECE into powerful diagnostic tools for long-term academic planning. This shift has profound implications for educational policy, enabling evidence-based student placement, targeted support for at-risk learners, and data-informed curriculum reforms in science education across Nigeria.

The Basic Education Certificate Examination (BECE) in Nigeria serves as a national benchmark for assessing the competencies acquired during the nine-year basic education cycle. It plays a central role in determining students' progression to senior secondary school and placement into science or arts streams (Imoh, Bassey, Essien, Udoh, and Ekarika, 2025). Presently, BECE relies predominantly on paper-based, standardized assessment formats, consisting of multiple-choice and short-answer questions designed to evaluate cognitive knowledge rather than higher-order thinking or problem-solving abilities (Adekemi, Okoye, and Lawal, 2024). While this format supports large-scale comparability, it provides limited diagnostic information on individual

students' conceptual understanding or learning progression in STEM-related subjects such as Basic Science, Mathematics, and Basic Technology (Ogunleye and Olatunji, 2023).

Furthermore, BECE assessment practices emphasize summative evaluation, offering aggregate scores without disaggregated feedback on specific skill domains or misconceptions (Nweke, Ogbaga, and Olodu, 2021). This approach, though useful for national educational accountability, restricts educators' ability to make data-driven instructional decisions or identify learners at risk of underachievement in science disciplines (Okoye and Uzochukwu, 2022). Consequently, many students who achieve satisfactory BECE results later struggle in senior secondary science subjects, indicating that current assessment systems possess limited predictive validity (Imoh *et al.*, 2025). In the context of STEM education, the reliance on static testing methods neglects the multidimensional nature of scientific reasoning and inquiry. STEM learning involves experimentation, critical thinking, and hands-on engagement elements that are rarely assessed through traditional BECE formats (Mbogo and Mwangangi, 2024). The lack of integration of practical laboratory assessment, digital simulations, and performance-based evaluation contributes to the gap between assessed competencies and real-world scientific application (Ogunleye and Olatunji, 2023). As educational systems worldwide adopt technology-enhanced and AI-driven approaches to assessment, Nigeria's BECE system remains largely conventional, underscoring the need for reform toward more dynamic, predictive, and competency-based evaluation frameworks.

Limitations of Traditional Assessment Methods

Traditional assessment methods in education such as standardized paper tests, teacher-made exams, and periodic quizzes have long served as the primary means of evaluating student achievement. However, these approaches are increasingly criticized for their limited ability to capture complex learning processes, adaptability, and real-time student progress (Mbogo and Mwangangi, 2024). In STEM education, where understanding is often demonstrated through experimentation, reasoning, and problem-solving, traditional assessments are inadequate for evaluating higher-order cognitive and procedural skills (Tahir, Hassan, and Shagoo, 2024). The emphasis on rote memorization and summative evaluation diminishes the predictive power of such assessments, making them less effective in forecasting long-term performance or practical proficiency (Imoh *et al.*, 2025).

Another significant limitation lies in the subjectivity and inconsistency of scoring, particularly in essay-type questions or practical evaluations. Differences in teacher interpretation and grading standards can lead to measurement error, thereby reducing reliability and predictive validity (Rocconi, 2025). Additionally, traditional assessment methods lack real-time feedback mechanisms that would allow educators to intervene early in students' learning trajectories (Gu and Ericson, 2025). They also fail to account for contextual variables such as learning environment, motivation, and socio-economic background that influence student performance, resulting in incomplete representations of learner potential (Altukhi and Pradhan, 2025).

The absence of adaptive assessment capabilities is another major drawback. Traditional tests typically present uniform items to all students, disregarding differences in learning pace and cognitive development. Consequently, such assessments fail to personalize learning or accurately identify specific areas of difficulty (Viberg, Wasson, and Mikroyannidis, 2023). In Nigeria, where the BECE and similar examinations remain largely static, this limitation restricts the potential to

predict and improve science learning outcomes across diverse student populations. To enhance predictive validity and equity, there is an urgent need to transition from traditional assessment models toward AI-enabled, data-informed, and adaptive assessment frameworks that can better reflect student abilities and learning dynamics.

AI Approaches to Enhancing Predictive Validity

Artificial Intelligence (AI) provides powerful analytical and adaptive mechanisms that can significantly enhance the predictive validity of academic assessments by modeling student performance, diagnosing learning difficulties, and supporting data-informed interventions. Traditional assessment methods often fall short in anticipating long-term academic success because they rely on static test scores that do not capture complex learning dynamics. In contrast, AI integrates machine learning algorithms, predictive analytics, and diagnostic assessments to generate richer, evidence-based insights into students' cognitive and behavioral learning patterns (Gu and Ericson, 2025). These AI-based systems have the potential to transform early academic assessments such as Nigeria's Basic Education Certificate Examination (BECE) into dynamic predictors of students' readiness for advanced science and STEM courses.

Machine Learning Algorithms for Performance Prediction

Machine learning (ML) algorithms are at the core of AI's predictive capabilities. They analyze both historical and real-time student data to uncover patterns and forecast future performance with high precision (Wang, O'Neil, and Lin, 2024). Commonly used algorithms include decision trees, support vector machines (SVM), random forests, and artificial neural networks (ANNs), which can detect nonlinear relationships between variables influencing learning outcomes (Gu and Ericson, 2025). These models can integrate multiple data sources such as test scores, attendance, classroom participation, and socio-demographic variables to improve prediction accuracy in STEM performance (Tahir, Hassan, and Shagoo, 2024).

In early secondary education, particularly within the Nigerian BECE context, machine learning applications have demonstrated superior predictive capacity compared to traditional statistical methods (Imoh, Bassey, Essien, Udoh, and Ekarika, 2025). For instance, ANN-based models can simulate complex cognitive processes to forecast student achievement in science subjects, while decision trees can classify students into performance risk categories, aiding educators in early interventions (Altukhi and Pradhan, 2025). These predictive models contribute to personalized learning pathways, ensuring that instructional resources are tailored to the unique learning trajectories of each student.

Data Analytics and Early Warning Systems

AI-driven data analytics platforms enhance predictive validity by transforming raw student data into actionable intelligence that supports early detection and intervention for at-risk learners (Viberg, Wasson, and Mikroyannidis, 2023). Through continuous monitoring of student engagement, assignment submissions, and assessment scores, these systems establish Early Warning Systems (EWS) capable of flagging performance deviations before they result in failure or dropout (Li and Zhao, 2025). Such models operate on a combination of predictive analytics and rule-based thresholds that alert teachers or administrators when a learner's performance deviates significantly from expected patterns (Gu and Ericson, 2025).

In practical application, EWS can be integrated into BECE preparatory systems to identify students whose performance trends suggest potential difficulties in science or mathematics. These systems can then recommend targeted remedial interventions, tutoring, or adaptive learning modules to address the identified learning gaps (Imoh *et al.*, 2025). By enabling proactive rather than reactive educational support, AI-based data analytics significantly improves academic retention, student motivation, and overall predictive accuracy of early assessments (Altukhi and Pradhan, 2025).

AI-Driven Diagnostic and Formative Assessments

AI also enhances predictive validity through diagnostic and formative assessments that generate real-time insights into learners' conceptual understanding and skill acquisition. Unlike traditional summative assessments, AI-driven diagnostics continuously evaluate learning processes, enabling immediate feedback and adaptive instructional adjustments (Smart Learning Environments, 2025). These assessments employ natural language processing, pattern recognition, and adaptive testing algorithms to measure learning progression rather than static achievement levels (Viberg *et al.*, 2023).

In science education, AI-powered diagnostic systems can evaluate students' reasoning during laboratory simulations, problem-solving exercises, and conceptual explanations thus providing a more holistic picture of learning (Tahir *et al.*, 2024). By integrating feedback loops, these systems allow teachers to fine-tune instruction, leading to better alignment between student needs and teaching strategies. Moreover, the continuous nature of formative AI assessments allows for the refinement of predictive models as new data become available, thereby enhancing their reliability and validity over time (Gu and Ericson, 2025).

Such adaptive feedback mechanisms are particularly valuable in Nigeria's BECE framework, where diagnostic insights are currently underutilized. Implementing AI-driven formative assessments can bridge the gap between student performance monitoring and predictive modeling, ensuring that early assessments better reflect students' long-term potential in STEM disciplines.

Empirical and Conceptual Evidence in Nigeria and Africa

Empirical research across Africa increasingly demonstrates the potential of **Artificial Intelligence (AI)** to enhance the predictive validity of academic assessments by leveraging large-scale educational datasets and machine learning techniques. In Nigeria and other sub-Saharan African countries, educational policymakers and researchers are beginning to explore how AI-driven analytics can bridge the gap between early academic assessments and long-term learning outcomes, particularly in STEM education (Adekemi, Okoye, and Lawal, 2024). Conceptual and applied studies within this emerging field underscore both the transformative potential and the contextual challenges associated with AI adoption in educational evaluation systems.

Studies on AI in Early Academic Assessment

Recent empirical studies in Africa highlight the capacity of AI models to accurately forecast student performance at various educational levels. In Nigeria, several investigations have demonstrated that **machine learning algorithms applied to historical BECE scores** can predict subsequent achievement in science and mathematics with significant precision (Adekemi *et al.*, 2024; Imoh, Bassey, Essien, Udoh, and Ekarika, 2025). Using data-driven approaches such as regression analysis, random forest models, and neural networks, researchers found that BECE

results in Basic Science and Mathematics can serve as reliable indicators of student success in senior secondary school science subjects (Nweke, Ogbaga, and Olodu, 2021).

Beyond Nigeria, studies in Ghana, Kenya, and South Africa have confirmed the predictive strength of AI-based models in early academic assessment (Mbogo and Mwangangi, 2024). For example, in Kenya, adaptive learning systems using AI analytics identified learning trajectories that traditional testing overlooked, providing early interventions for students lagging behind in physics and mathematics (Mutisya and Rotich, 2023). Similarly, in South Africa, the integration of predictive models into e-learning platforms helped schools target remedial instruction more effectively, demonstrating improvements in science performance across participating schools (Tahir, Hassan, and Shagoo, 2024). Collectively, these findings affirm AI's potential to enhance educational equity by identifying learning disparities early and optimizing resource allocation.

Case Studies on Science Performance Prediction

Several **pilot case studies** in Nigeria and neighboring African nations have explored how AI-based predictive systems can inform science teaching and learning outcomes. For instance, Imoh et al. (2025) reported on a pilot project across selected Nigerian secondary schools where AI models trained on BECE science data successfully predicted student outcomes in subsequent chemistry and biology courses. The system categorized learners into risk levels high, medium, or low allowing teachers to deliver targeted remediation and differentiated instruction. Teachers in these schools reported improved instructional planning, more efficient grading, and enhanced ability to provide **early support for struggling learners**.

In Ghana, a similar AI-assisted assessment initiative introduced machine learning tools to predict junior secondary students' success in integrated science. Results indicated that schools using AI-based prediction tools recorded a 17% improvement in pass rates compared to those relying solely on traditional testing (Kwarteng and Osei, 2024). These pilot implementations underscore the effectiveness of AI in generating actionable educational insights, thereby increasing the **predictive validity and pedagogical relevance** of early science assessments.

Additionally, AI-driven dashboards and learning analytics tools have been piloted in Nigerian teacher training institutions, helping preservice teachers understand data patterns that inform individualized instruction (Okoye and Uzochukwu, 2022). Such models not only enhance student outcomes but also foster AI literacy among educators, ensuring sustainability and scalability of the technology within the educational ecosystem.

Lessons Learned from Regional Implementations

While empirical evidence across Africa confirms the promise of AI in educational prediction, several **lessons** have emerged regarding successful implementation. First, studies emphasize the importance of high-quality, structured educational data as the foundation for reliable machine learning models (Mbogo and Mwangangi, 2024). In many African contexts, incomplete or inconsistent educational records limit the training and accuracy of AI systems. Second, effective adoption requires teacher capacity building and AI literacy to ensure educators can interpret predictive insights and integrate them into classroom practice (Adekemi *et al.*, 2024).

Furthermore, infrastructural and policy factors are critical determinants of success. Many African countries face challenges related to **digital infrastructure, data privacy, and equitable access** to AI technologies (Altukhi and Pradhan, 2025). These challenges underscore the need for policies that align AI integration with local educational goals, ensuring contextual adaptation to curricula, assessment frameworks, and linguistic diversity. For instance, context-sensitive AI models must account for local grading systems, socioeconomic variations, and language-of-instruction differences that influence learning outcomes (Mutisya and Rotich, 2023).

Overall, empirical and conceptual evidence across Nigeria and Africa highlights that the successful use of AI in early academic assessment depends not only on technological sophistication but also on **contextualization, human capacity, and policy coherence**. These lessons provide a roadmap for integrating AI into BECE and STEM assessments in Nigeria, where predictive validity can be significantly strengthened through inclusive, data-informed, and context-aware educational reforms.

Challenges and Ethical Considerations

The integration of Artificial Intelligence (AI) in early academic assessments offers transformative opportunities for educational systems in Nigeria and Africa. However, the implementation process is fraught with challenges that affect reliability, scalability, and ethical soundness. These challenges include issues of data quality, privacy, and security; teacher preparedness and AI literacy; infrastructure and funding constraints; and policy gaps that limit effective deployment. Understanding these constraints is essential to ensure that the use of AI enhances rather than compromises predictive validity and educational equity (Altukhi and Pradhan, 2025; Viberg, Wasson, and Mikroyannidis, 2023).

Data Quality, Privacy, and Security

The **accuracy and fairness of AI predictions** rely heavily on the quality, comprehensiveness, and security of student data. In many Nigerian and African educational systems, datasets are fragmented, inconsistent, or incomplete, which undermines model reliability and predictive accuracy (Altukhi and Pradhan, 2025). For instance, missing or erroneous entries in BECE datasets can result in biased predictions that disproportionately affect students from under-resourced schools. Furthermore, the storage and processing of sensitive student information raise **ethical concerns about data privacy, consent, and ownership**. Without robust data governance policies, student information could be misused or exposed to cyber threats, eroding public trust in AI-based systems (UNESCO, 2023).

As highlighted by Gu and Ericson (2025), establishing transparent data collection frameworks and implementing strong encryption and anonymization standards are critical to safeguarding student information. Ethical AI frameworks must ensure compliance with privacy laws such as the **Nigeria Data Protection Act (NDPA, 2023)**, promoting accountability and protecting learners' rights. Thus, enhancing data quality and security is foundational for sustaining the predictive validity of AI-driven academic assessments.

Teacher Preparedness and AI Literacy

Teachers play a central role in mediating the use of AI in classroom assessment. However, a major barrier to effective implementation is the **low level of AI literacy and digital competence among**

educators in Nigeria (Rocconi, 2025). Many teachers lack sufficient training in interpreting AI-generated analytics or integrating machine learning insights into instructional decisions. This limits the potential of AI tools to inform formative assessment and targeted interventions.

According to Tahir, Hassan, and Shagoo (2024), the success of AI in education depends not only on technological availability but also on the **pedagogical readiness** of teachers to adapt to data-driven instruction. Professional development programs focusing on AI literacy, data interpretation, and ethical awareness are therefore essential. Without this foundation, teachers may view AI systems as intrusive or unreliable, resulting in resistance to adoption. In this regard, capacity-building initiatives supported by educational ministries and teacher training institutions can bridge the competency gap and promote effective human–AI collaboration.

Infrastructure and Funding Constraints

Reliable infrastructure is a prerequisite for AI implementation in educational contexts. Unfortunately, **many Nigerian schools face significant challenges related to inadequate digital infrastructure**, including limited internet connectivity, unreliable electricity supply, and insufficient access to devices and software (UNESCO, 2023). These infrastructural limitations create a digital divide between urban and rural schools, hindering equitable adoption of AI-enhanced assessments.

Moreover, **funding constraints** restrict the scalability and sustainability of AI systems. Developing and maintaining AI-based platforms require substantial investment in technology procurement, teacher training, and technical support (Mbogo and Mwangangi, 2024). Public schools, especially in rural areas, often lack the financial resources to implement such systems effectively. International agencies such as UNESCO (2023) and the African Union (2024) have emphasized the need for **public–private partnerships** to mobilize resources, promote technological inclusion, and ensure that AI-driven innovations benefit all learners irrespective of socioeconomic background.

Policy Gaps and Implementation Barriers

Despite growing interest in educational AI, **policy frameworks in Nigeria and many African countries remain underdeveloped** with regard to ethical regulation, data protection, and accountability mechanisms (Viberg *et al.*, 2023). The absence of clear national standards for AI integration in assessment and learning analytics creates uncertainty for schools and developers. Weak regulatory oversight can result in inconsistent implementation and potential misuse of predictive data for non-educational purposes.

In addition, **institutional inertia and bureaucratic barriers** slow down the adoption of innovative AI solutions (Imoh *et al.*, 2025). Limited collaboration between policymakers, researchers, and technology providers often leads to fragmented initiatives that lack long-term sustainability. Addressing these policy gaps requires comprehensive frameworks that define ethical standards, data protection measures, and mechanisms for monitoring the performance of AI systems in education. Establishing **AI governance councils within education ministries** could ensure accountability, transparency, and alignment with national educational goals.

Ultimately, overcoming these challenges is essential to harness the full potential of AI for improving the predictive validity of early academic assessments. A coordinated effort involving

educators, policymakers, technologists, and researchers will foster a more equitable, ethical, and data-informed educational ecosystem in Nigeria.

Implications for Educational Practice and Policy

The integration of Artificial Intelligence (AI) into early academic assessment presents transformative implications for educational practice, teacher development, and policy design in Nigeria and across Africa. As educational systems evolve toward data-driven decision-making, AI-enhanced predictive assessments can inform **instructional improvement, personalized learning, and systemic reform**. These implications extend to strengthening STEM instruction, embedding AI literacy in teacher training, and developing policy frameworks that promote sustainable and ethical AI integration (Adekemi, Okoye, and Lawal, 2024; Viberg, Wasson, and Mikroyannidis, 2023).

Enhancing STEM Instruction and Early Intervention Strategies

AI-enhanced assessment tools provide actionable insights into students' learning trajectories, enabling **targeted intervention strategies** in STEM classrooms. Through predictive analytics and adaptive learning platforms, teachers can identify patterns of misconception, monitor conceptual progress, and tailor instruction to individual student needs (Tahir, Hassan, and Shagoo, 2024). For example, AI-based systems that analyze BECE science performance data can flag students at risk of underperforming in subsequent science courses, allowing teachers to implement early remediation.

According to Gu and Ericson (2025), AI-driven formative assessments support continuous feedback loops that strengthen conceptual understanding in science and mathematics. Such systems enhance student engagement and mastery by aligning instructional pacing with each learner's cognitive readiness. In Nigeria's context, this approach can significantly improve science performance and retention rates, particularly among learners in under-resourced schools. Therefore, integrating AI in classroom practice should focus on **enhancing diagnostic precision and adaptive pedagogy**, thereby improving the predictive validity of early assessments and long-term academic success.

Integrating AI Tools into Teacher Training Programs

The success of AI-enhanced education depends largely on **teacher competence and confidence** in interpreting and applying data-driven insights. Embedding AI literacy and digital pedagogy within both **pre-service and in-service teacher education programs** is critical for building a workforce capable of leveraging AI tools effectively (Rocconi, 2025). Teacher training institutions in Nigeria must revise curricula to include modules on **educational data analytics, AI ethics, and human-AI collaboration**.

Imoh *et al.* (2025) emphasize that when teachers are trained to interpret AI-generated reports, they can make informed instructional decisions that enhance assessment validity and fairness. Furthermore, continuous professional development programs should expose teachers to practical applications of AI in lesson planning, grading, and formative evaluation. As Altukhi and Pradhan (2025) argue, fostering teacher AI literacy promotes a culture of innovation and evidence-based pedagogy, ensuring that AI becomes a supportive, rather than disruptive, element in classroom assessment.

In this regard, partnerships between teacher education institutions, technology firms, and ministries of education are vital to facilitate access to AI tools, provide technical support, and promote **inclusive capacity building** across public and private educational systems.

Policy Recommendations for Sustainable AI Adoption

To ensure that AI-enhanced assessments are implemented ethically and sustainably, **robust policy frameworks** are required at both national and institutional levels. Governments and educational stakeholders should establish **guidelines for responsible AI use**, addressing issues of data privacy, transparency, fairness, and accountability (UNESCO, 2023). Clear national standards for AI in education can help mitigate misuse, promote interoperability, and ensure equity across different school contexts.

Moreover, sustainable AI integration demands **investment in infrastructure and digital inclusion**. Policymakers must prioritize funding for broadband internet access, digital devices, and educational software, particularly in rural and underserved regions (Mbogo and Mwangangi, 2024). Public–private partnerships can play a strategic role in financing AI infrastructure and facilitating technology transfer.

Finally, policy initiatives should promote **research–practice collaborations**, enabling continuous evaluation of AI systems’ impact on assessment validity and student learning outcomes (Viberg et al., 2023). Establishing an **AI-in-Education Regulatory Framework** under Nigeria’s Federal Ministry of Education could help align innovation with ethical and pedagogical standards, ensuring that AI adoption supports inclusive, equitable, and future-ready learning environments.

Conclusion and Recommendations

The integration of Artificial Intelligence (AI) into educational assessment represents a transformative approach to understanding and improving student learning outcomes. In Nigeria, the Basic Education Certificate Examination (BECE) serves as a critical determinant of students’ academic trajectories, particularly in science and other STEM disciplines. Enhancing its predictive validity through AI-driven models offers new possibilities for identifying learning patterns, forecasting future performance, and supporting data-informed instructional decisions.

AI-enhanced assessment systems have the capacity to provide early warning signals for students at risk of underperformance, enabling timely interventions that strengthen conceptual understanding and mastery. By incorporating adaptive learning platforms, machine learning algorithms, and real-time diagnostic tools, educators can personalize instruction and address learning gaps more effectively. This approach aligns with modern educational goals that emphasize competency, problem-solving ability, and lifelong learning skills. However, the benefits of AI integration can only be realized when challenges such as data quality, teacher preparedness, digital infrastructure, and ethical regulation are properly addressed. Ensuring data privacy and fairness, improving AI literacy among teachers, and investing in educational technology are critical steps toward sustainable adoption. Collaborative efforts among government bodies, technology providers, researchers, and educational institutions are essential to create inclusive, transparent, and accountable AI systems that serve all learners equitably.

Recommendations:

1. Strengthen teachers' AI competencies through targeted training programs.
2. Improve digital infrastructure and access to AI-enabled tools.
3. Foster partnerships between educational institutions and AI developers.
4. Implement policy frameworks that ensure ethical, equitable, and sustainable use of AI in assessment.

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META-ANALYSIS OF THE RELATIONSHIP BETWEEN MATHEMATICS TEACHERS' DIGITAL FACTORS AND STUDENTS' ACHIEVEMENT: IMPLICATION FOR ADOPTION OF ARTIFICIAL INTELLIGENCE IN LEARNING

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Abstract

The paper presents a meta-analysis of the studies on the relationship between mathematics teachers' digital factors such as digital skills, pedagogical integration and attitudes toward technology and students' achievement in mathematics. The aim is to inform educators, policymakers and stakeholders on strategic approaches to empower mathematics teachers' digital readiness and effectively leverage AI innovations to improve student achievement in mathematics education. It focused on implications of mathematics teachers' digital factors for artificial intelligence (AI) adoption in learning. The review used PRISMA framework to extract 14 empirical studies published from 2020 to 2025, which were reviewed systematically to synthesize evidence on how teachers' digital competencies influence mathematics-learning outcomes. The analysis highlighted that teachers' proficiency and positive attitudes toward digital tools particularly AI-based technologies like ChatGPT significantly enhanced student engagement, conceptual understanding and academic performance. AI integration supports personalized instruction, real-time feedback and student retention, thereby augmenting teachers' instructional effectiveness. However, challenges such as limited digital infrastructure, insufficient training, anxiety toward AI adoption and ethical concerns hinder widespread implementation. It was concluded that artificial intelligence (AI) adoption in mathematics education has a largely positive impacts on students' achievement, engagement and to some extent on teachers' effectiveness. Incorporating AI into teaching and learning enhanced students' digital competencies and retention, while also improving academic outcomes. Similarly, AI tools like ChatGPT enabled personalized instruction that deepen students' conceptual understanding and boost engagement for better learning performance. The paper recommended that government and stakeholder in the communities should give much concern on the provisions of conducive ICT environments and facilities to enhance digital skills and smoothen the integration of technology in teaching and learning science.

Keywords: *Mathematics Teachers' Digital Factors, Students Achievement, Artificial Intelligence, and Learning Outcomes*

Introduction

The relationship between mathematics teachers' digital factors and student achievement is increasingly non-negligible in the context of evolving educational technologies including artificial intelligence (AI) (Meylani, 2024). Torrato *et al.* (2020) described digital factors as encompassing teachers' proficiency with digital tools, pedagogical integration of technology and attitudes toward digital adoption. These factors significantly influence students' learning outcomes in mathematics (Meylani, 2024; Torrato *et al.*, 2020). Research by Awofala *et al.* (2025) indicates that effective digital integration in mathematics instruction can enhance conceptual understanding, engagement, and problem-solving skills vital to academic success. However, disparities in teachers' digital competencies and resource availability create uneven learning experiences with consequential

effects on student achievement (Nja *et al.*, 2023). Given the transformative potential of AI in learning environments, it is important to understand the relationship between AI adoption and mathematics outcome for optimized educational practices and outcomes.

Additionally, teachers' digital readiness comprises not only technical skills but also pedagogical adaptation for digital environments (Sardauna, 2025). Sunday *et al.* (2025) posited that understanding the nexus between digital readiness and pedagogical adaptation is essential for meaningful mathematics instruction in digital classrooms. The adoption of digital tools by mathematics teachers influences instructional design, interaction patterns and feedback mechanisms that shape students' cognitive development (Asanre *et al.*, 2024; Eke, 2024; Falebita, 2024). For example, Aggarwal *et al.* (2024) stated that teachers adept at integrating interactive software and adaptive learning platforms helped to personalize learning trajectories and thereby address individual student needs more effectively. Conversely, Adigun *et al.* (2025) opined that limited digital fluency might hinder teacher-student interaction and restrict the use of formative assessment tools, which negatively influences on students' achievement. Studies by Ngonso *et al.* (2025) and Ogoke *et al.* (2025) have shown the importance of sustained professional development and institutional support to bridge these gaps.

The implications for AI adoption in learning are multifaceted as AI technologies offer prospects for intelligent tutoring, real-time analytics and personalized feedback in mathematics education (Tang, 2025). AI systems can augment teachers' instructional capabilities by analyzing student performance data to tailor interventions and adapt content dynamically (Ayanwale *et al.*, 2024). This synergy can enhance achievement by providing scaffolding aligned with each learner's proficiency level thus fostering mastery and motivation. However, successful AI integration depends on teachers' competence with digital tools and their openness to adopting AI-based instructional strategies (Egara and Mosimege, 2024; Ikechukwu *et al.*, 2024). According to Egara and Mosimege (2024), resistance to change, lack of digital infrastructure and concerns about AI's ethical and practical implications emerge as barriers in this regard.

Several studies by Adewale *et al.* (2024), Egara *et al.* (2025) and Ngonso *et al.* (2025) have explored the mediating effects of teacher digital factors on student achievement in mathematics within AI-enabled environments. These investigations revealed that teachers' digital self-efficacy and positive attitudes toward technology are strong predictors of effective AI use and consequent student gains. Conversely, Nwokorie and Onichakwe (2024) identified insufficient training and lack of technological confidence as factors limits suboptimal use of AI tools and their impact on learning outcomes. The interplay between teachers' digital competencies and AI adoption thus constitutes a critical area for research and educational policy focus, especially in settings undergoing digital transformation (Meylani, 2024; Awofala *et al.*, 2025).

Practical implications for educational systems include the need to invest in teacher training programmes that emphasize digital literacy, pedagogical adaptation and AI integration (Ogoke *et al.*, 2025). Policymakers should facilitate equitable access to digital resources and create frameworks that encourage experimentation with AI-enhanced teaching while addressing privacy, bias and inclusivity issues (Anyim and Manabete, 2024). In addition, Okorie (2022) and Rasheed *et al.* (2025) opined that prioritizing teacher empowerment with digital skills and AI awareness, schools could foster environments conducive to higher student achievement in mathematics.

Moreover, continuous evaluation of AI tools' effectiveness and alignment with curriculum standards is vital to sustain positive outcomes.

This meta-analysis synthesizes extant research on the relationship between mathematics teacher digital factors and student achievement. It emphasized AI's role in reshaping teaching and learning dynamics. By analytically appraising empirical evidence on the AI application in mathematics education, this work identifies best practices, knowledge gaps, and strategic directions to enhance AI adoption in mathematics education. It aims to inform educators, administrators and policymakers on ways to foster digitally proficiency of mathematics teachers who would leverage AI to improve student achievement effectively and equitably.

Objectives Of the Review

The review objectives focus on examining the relationship between mathematics teachers' digital factors and students' achievement. The review emphasis on adoption implications for artificial intelligence (AI) in learning environments. The rationale for this review arises from the growing integration of digital technologies and AI in education, which demand critical assessment of how teachers' digital competencies, attitudes and access to technology influence student performance in mathematics. Understanding these dynamics is important to identifying the enablers and barriers in leveraging digital tools and AI to improve educational outcomes.

Equally important is to investigate the specific digital factors related to teachers' digital literacy, use of digital pedagogical strategies and openness to new technologies. The review evaluates how these affect students' engagement and mastery of mathematical concepts. Given that mathematics achievement is often influence by instructional quality and learner interaction with digital media, clarifying this nexus informs targeted teacher training and technology implementation strategies. Furthermore, the review aims to explore how AI adoption can transform teaching practices by providing personalized learning pathways and intelligent feedback, which could enhance achievement if appropriately integrated. The systematic review also aims to identify challenges teachers face in adopting digital and AI tools in mathematics instruction. Identifying these barriers will help stakeholders design supportive frameworks that facilitate smoother digital transformation within mathematics education.

Research Questions

The following research questions guided the study:

1. How do mathematics teachers' digital competencies, attitudes and technology use impact on students' achievement?
2. What are the implications of AI adoption in teaching mathematics teaching on students' achievement?
3. What challenges and supports affect the adoption of digital and AI tools by mathematics teachers?

Research Methodology

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were adopted to ensure a transparent, comprehensive, and replicable approach in conducting this meta-analysis of the relationship between mathematics teachers' digital factors and students' achievement, with implications for AI adoption in learning. PRISMA provides a standardized

framework comprising a checklist of essential reporting items and a flow diagram to document the systematic review process, including literature search, study screening, and selection. Given the focus on digital and AI factors in education, PRISMA-ScR (extension for scoping reviews) was especially suitable to outline protocol components such as research questions, data sources, inclusion criteria, and synthesis. A structured and replicable literature search was executed across multiple electronic databases including ERIC, Scopus, Web of Science, and Google Scholar to capture interdisciplinary studies in education technology, mathematics teaching, and AI application in learning. Grey literature including conference proceedings, educational technology reports, and government policy documents was also reviewed to supplement findings. The search spanned publications from 2010 to the present to reflect recent developments in digital teaching and AI integration. Keywords and phrases used in Boolean combinations included "mathematics teacher digital competence," "student achievement," "digital pedagogy," "AI in education," and "technology adoption in teaching."

The review adhered to PRISMA standards in reporting methodology and findings, including the presentation of a flow diagram detailing study identification, screening, eligibility assessment, and inclusion phases. This transparent process supports reproducibility and clarity in understanding the evidence on the relationship between mathematics teacher digital factors, student achievement, and AI adoption implications in learning.

Results And Findings

The flowchart in Figure 1 outlined the process and results of a systematic review using PRISMA framework as methodology. The review identified 2,576 records were from multiple databases: Scopus and Web of Science (1,052), Education Source (EBSCO) and ProQuest Education Database (317), ScienceDirect and Cochrane Library (369), ERIC (324), and ACM Digital Library with IEEE Xplore (514). After duplicate removal and initial relevance screening, only 136 records were retained for further evaluation, while 2,440 records were excluded. Next, 29 full-text articles were assessed in detail for eligibility, with 110 full-texts excluded for reasons such as irrelevance to digital factors or lacking sufficient methodological quality. A total 14 studies were included in the final synthesis: 11 were journal articles and 3 were conference proceedings. This careful filtering and selection of these studies demonstrated adherence to the PRISMA standard, which enhanced transparency and replicability in systematic reviews. Each phase of study selection, exclusion and inclusion in numeric detail was documented—just as in the comparative example where filters and eligibility criteria gradually narrowed down studies to those of the highest relevance to the research question.

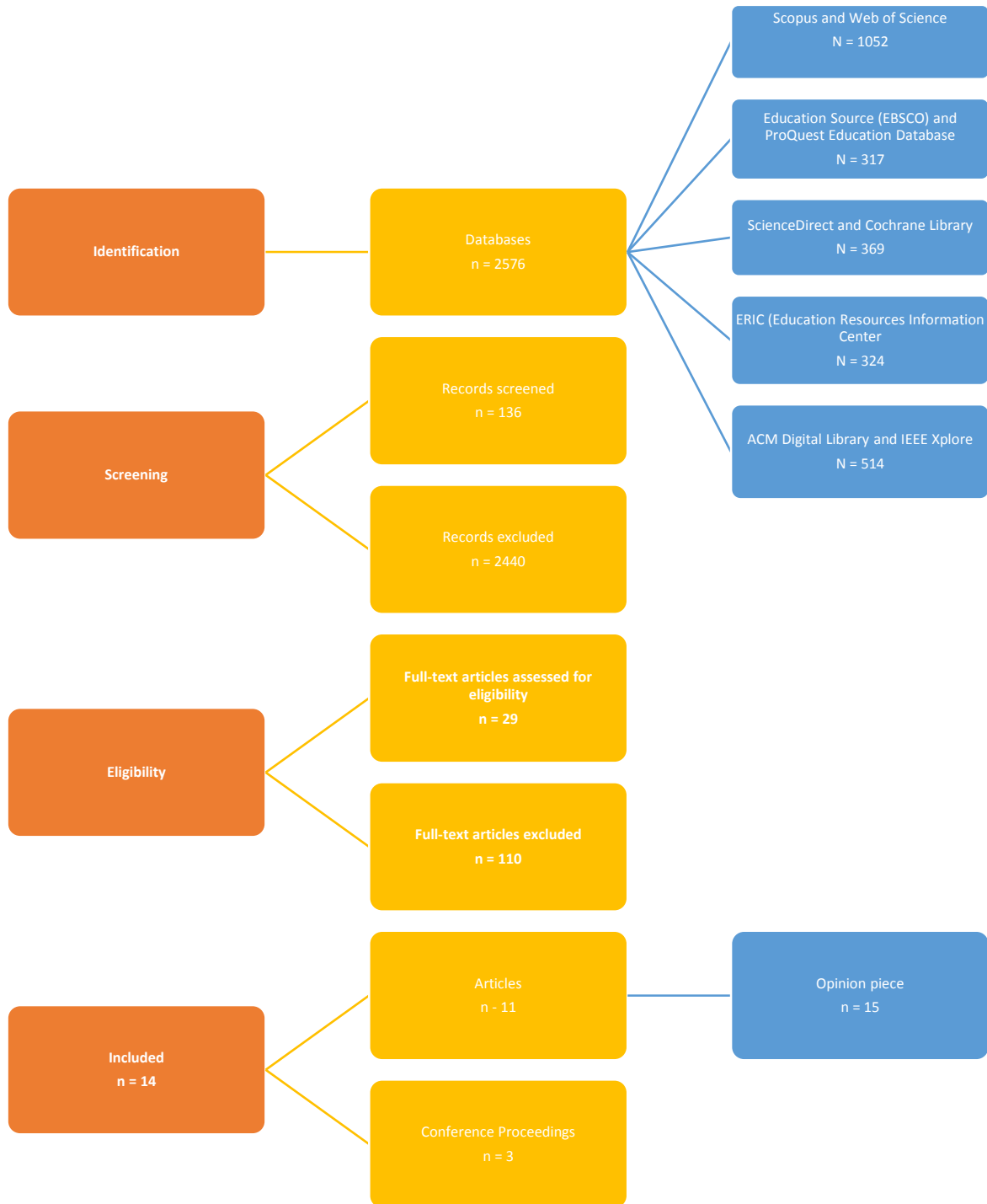


Figure 1: Result of the SLR Using PRISMA Flowchart

The majority of the studies in Table 2 focus on the role of artificial intelligence (AI) in enhancing mathematics education. The studies particularly emphasis on the perceptions, adoption impacts and effectiveness and challenges of AI tools among teachers and students. Ogoke *et al.* (2025) investigated how AI adoption affects student achievement and retention by integrating AI within

teaching and learning processes. The study emphasized that AI improved engagement and digital competencies. Similarly, Asanre *et al.* (2024) and Falebita (2024) explore teachers' perceptions and the challenges—such as anxiety—related to AI integration among pre-service mathematics teachers. The finding highlighted that the human factors influencing effective AI use in the classrooms. These studies collectively showed the significance of teacher readiness and attitudes toward AI for successful adoption in mathematics education.

Several studies specifically explore AI tools like ChatGPT in mathematics instruction with focus on both students' and teachers' experiences. Egara and Mosimege (2024) provided qualitative insights into how ChatGPT facilitated personalized teaching and learning, through improving instructional effectiveness while also noting obstacles like access to technology. Their follow-up study (Egara *et al.*, 2025) examined secondary students' perceptions and finding showed that AI tools help students better understand mathematical concepts and increase engagement. This they argued contributed positively to academic performance. This line of research revealed that AI's potential to tailor mathematics education to individual learning needs and enable richer interaction with mathematical content.

Other studies widen the scope by integrating AI adoption themes within broader educational contexts. For example, Rasheed *et al.* (2025) uniquely apply mathematical and computer logic concepts to teaching Ifá religious practice. The study demonstrated the interdisciplinary applications of AI in mathematics education. Moreover, researches by Ojo (2024) and Adigun *et al.* (2025) examined preservice teacher development and intentions to adopt AI in Nigerian inclusive classrooms. Finding from their studies reflected efforts to prepare future educators for AI-enhanced pedagogy education. Additionally, studies by Bali *et al.* (2024); Yakubu (2024) and Ayanwale *et al.* (2024) assessed the emerging trends and teachers' trust in AI technologies across STEAM disciplines. The studies positioned mathematics education within a larger framework of AI adoption in education. These studies collectively highlighted the varied focus areas that contribute to understanding and shaping AI's evolving role in teaching and learning mathematics.

Table 2: Selected Studies and their Focus Areas and Sources

S/N	Authors	Year	Title	Focus	Source / Notes
1	Ogoke, C. J., <i>et al.</i>	2025	Application of artificial intelligence in the teaching and learning of mathematics: Implication for achievement and retention	Mathematics Education & AI	Eureka: Journal of Educational Research
2	Asanre, A. A., <i>et al.</i>	2024	Teachers' perception of AI integration in mathematics teaching	Mathematics Education	Journal Article, 2024
3	Falebita, O. S.	2024	Anxiety and adoption of AI tools among mathematics preservice teachers	Mathematics Education	Interdisciplinary Journal of Education Research
4	Egara, F. O., & Mosimege, M.	2024	Exploring the integration of AI-based ChatGPT into mathematics instruction	Mathematics Education	Education Sciences
5	Egara, F. O., <i>et al.</i>	2025	Secondary students' perceptions of AI ChatGPT in mathematics learning	Mathematics Education	Journal of Education (University of KwaZulu-Natal),

S/N	Authors	Year	Title	Focus	Source / Notes
6	Rasheed, R. T., <i>et al.</i>	2025	Application of mathematics logical reasoning and computer logic in teaching Ifá religious practice	Math Education Concepts in Religious Practice	THEME, 114
7	Ojo, O.	2024	Promoting AI education in K–12 through preservice teacher development	Mathematics Education	Journal Article, 2024
8	Adigun, O. T., <i>et al.</i>	2025	Understanding pre-service teachers' intention to adopt and use AI in Nigerian inclusive classrooms	Mathematics Education	Frontiers in Education, Vol. 10, p.1519472
9	Bali, B., <i>et al.</i>	2024	Analysis of emerging trends in artificial intelligence for education in Nigeria	Mathematics & AI Education	Discover Artificial Intelligence, 4(1), 110
10	Ayanwale, M. A., <i>et al.</i>	2024	Exploring STEAM teachers' trust in AI-based educational technologies	STEAM (Includes Mathematics)	Discover Education, 3(1), 44
11	Asanre, A. A., <i>et al.</i>	2024	Perceptions of AI integration in senior secondary mathematics teaching	Mathematics Education	Journal Article, 2024
12	Egara, F. O., & Mosimege, M.	2024	AI integration in mathematics instruction	Mathematics Education	Education Sciences, 14(7), 742
13	Falebita, O. S.	2024	AI tool adoption by mathematics preservice teachers	Mathematics Education	Interdisciplinary Journal of Education Research, 6, 1-13
14	Ogoke, C. J., <i>et al.</i>	2025	AI in math teaching and learning	Mathematics Education	Eureka: Journal of Educational Research, 3(2), 136-143

The studies summarized in Table 3 collectively demonstrated that artificial intelligence (AI) adoption in mathematics education positively affects both student achievement and teaching effectiveness. Ogoke *et al.* (2025) showed through a combined quantitative and qualitative methodology that AI tools enhance student engagement and build digital competencies. The study posited that adoption of AI tools were linked strongly to improved academic performance and retention in mathematics. Similarly, a mixed-methods study by Ogoke *et al.* highlights how AI integration not only advances student outcomes but also significantly improves teachers' digital skills. The finding equally reinforced the link between educator proficiency with AI and student success in mathematics.

Further supporting these findings, Egara *et al.* (2025) reported that secondary students perceive AI tools, such as ChatGPT, as beneficial for grasping mathematical concepts, which they said lead to greater engagement and better academic results. Qualitative research by Egara and Mosimege (2024) adds that ChatGPT facilitates personalized instruction and enhances teaching effectiveness, though it also identifies barriers such as unequal access to technology. Together, these studies underscore the transformative potential of AI in mathematics education while highlighting the challenges that need addressing to maximize its educational benefits.

Table 3: Summary of Selected Studies on Impacts of AI Adoption on Mathematics Education and Student Achievement

Article Title	Methodology	Findings
Application of artificial intelligence in the teaching and learning of mathematics: Implication for achievement and retention (Ogoke <i>et al.</i> , 2025)	Quantitative and qualitative analysis of AI integration in mathematics teaching and learning environments	AI adoption enhances student achievement through improved engagement and digital competencies; teachers' use of AI positively correlates with student retention and achievement.
Secondary students' perceptions of AI use in mathematics learning and impacts on achievement (Egara, Mosimege & Mosia, 2025)	Survey and perception study of secondary school students' use of AI tools like ChatGPT in math learning	Students perceive AI tools as helpful for understanding math concepts, leading to better academic performance and engagement.
AI in math teaching and learning: Effects on digital competencies and student outcomes (Ogoke <i>et al.</i> , 2025)	Mixed-methods research including teacher observations, student assessments, and competency evaluations	AI integration improves teachers' digital competencies, which positively influence student learning outcomes in mathematics.
Exploring the integration of AI-based ChatGPT into mathematics instruction (Egara & Mosimege, 2024)	Qualitative research including teacher interviews and classroom observations	ChatGPT adoption facilitates personalized instruction and increases teaching effectiveness, though challenges like technology access persist.

Table 4 summarized studies on the attitudes and perceptions of mathematics teachers toward AI adoption and the associated challenges. The studies highlighted a positive attitudes and perceptions towards AI adoption. For instance, Asanre *et al.* (2024) showed through survey-based descriptive analysis that teachers recognize AI as a valuable tool for enhancing mathematics instruction but struggle with insufficient training and lack of resources. Similarly, their focused study on senior secondary teachers confirms positive attitudes alongside barriers such as inadequate infrastructure and limited professional development opportunities that impede broader AI integration.

Research centered on preservice teachers offered further insight into the factors influencing AI adoption intentions. Ojo (2024) combined qualitative and quantitative methods to demonstrate that professional development programmes including training and mentoring are critical in preparing preservice teachers for effective AI use. Similarly, Adigun and colleagues (2025) expanded on this by identifying perceived usefulness, ease of use and available support structures as key determinants of pre-service teachers' intentions to adopt AI. The study found positive attitude toward AI adoption, thus accentuating the importance of attitudinal and contextual influences on technology acceptance in education.

Other studies emphasize the role of trust and systemic conditions in AI adoption within mathematics and STEAM education. Ayanwale *et al.* (2024) use structural equation modeling to reveal that teachers' trust in AI significantly affects their willingness to implement AI technologies, with variables such as gender and teaching experience moderating trust levels. Bali, Garba, and colleagues' (2024) highlighted increasing AI awareness and adoption in Nigerian education but stressed the need for strategic policies and improved infrastructure to support sustainable and large-scale implementation in mathematics classrooms. Together, these findings provided a comprehensive view of teachers' attitudes and the multifaceted factors shaping AI adoption in mathematics education.

Table 4: Summary of Studies on Teachers' Attitudes, Perceptions, Trust and Intentions Regarding AI Adoption in Mathematics Education

Article Title	Methodology	Findings
Teachers' perceptions of AI integration in mathematics teaching (Asanre, Taiwo & Odupe, 2024)	Survey-based descriptive analysis of mathematics teachers' attitudes towards AI	Teachers generally perceive AI positively as a tool to enhance mathematics teaching but face challenges related to training and resource availability.
Preservice teacher development for AI adoption; supports and challenges (Ojo, 2024)	Qualitative and quantitative assessment of preservice teachers' readiness and development programs	Professional development is critical for successful AI adoption; supports such as training and mentoring improve adoption intentions.
Intention and factors affecting pre-service teachers' AI adoption (Adigun, Tijani <i>et al.</i> , 2025)	Mixed methods using surveys and interviews on pre-service teachers' intentions and influencing factors	Intention to adopt AI is influenced by perceived usefulness, ease of use, and support structures, highlighting importance of attitudinal and contextual factors.
Trends in AI education including implications for mathematics teaching and learning (Bali, Garba <i>et al.</i> , 2024)	Literature review and trend analysis of AI integration in Nigerian education	Increasing awareness and adoption of AI in education, with an emphasis on the need for policy and infrastructure to support scalable use in math classrooms.
Trust in AI technologies among STEAM teachers including mathematics (Ayanwale, Adelana & Odufuwa, 2024)	Structural equation modelling and survey of STEAM teachers' trust in AI systems	Trust plays a crucial role in adoption; higher trust correlates with willingness to use AI in teaching; gender and teaching experience have varying impacts on trust levels.
Perceptions of AI integration in senior secondary mathematics teaching (Asanre, Taiwo & Odupe, 2024)	Survey analysis focused on senior secondary mathematics teachers' perceptions	Positive attitudes towards AI integration exist, but challenges remain including lack of infrastructure and limited training opportunities hindering widespread adoption.

Studies summarized in Table 5 revealed that mathematics teachers face significant challenges in adopting AI tools. These challenges are often linked to anxiety, inadequate training and limited infrastructure. Falebita (2024) identifies high anxiety levels among preservice teachers regarding AI adoption in the classroom, which demonstrated that their readiness to use AI effectively is tied closely to the quality and extent of training and exposure they receive. This anxiety can hamper confidence and slow down the integration process. This indicated both psychological and technical barriers. Egara and Mosimege (2024) further illustrated that practicing mathematics teachers struggle with insufficient digital infrastructure and lack of ongoing technical support. This the duo posited act as major obstacles to widespread AI integration despite generally positive attitudes toward its potential benefits.

On the support side, these studies emphasize the crucial role of targeted training and institutional backing in facilitating successful AI adoption. Falebita's second study (2024) showed moderate adoption rates among preservice teachers, with confidence, perceived usefulness of AI tools and supportive organizational environments playing key roles in actual usage. These findings suggest that addressing both emotional factors like anxiety and systemic issues such as infrastructure and training needs can significantly enhance teachers' ability and willingness to adopt AI in mathematics education. This could ultimately lead to more effective and innovative instructional practices.

Table 5: Summary of Studies on Challenges and Supports in AI Adoption by Mathematics Teachers

Article Title	Methodology	Findings
Teacher anxiety and readiness regarding AI tool adoption (Falebita, 2024)	Survey and mixed-method study of preservice mathematics teachers	High levels of anxiety observed among preservice teachers concerning AI tool adoption; readiness influenced by training and exposure.
Challenges and prospects of AI integration in mathematics instruction (Egara & Mosimege, 2024)	Qualitative and survey-based research with practicing math teachers	Identified challenges include lack of digital infrastructure, inadequate teacher training, and limited technical support; prospects are positive with proper support.
Actual AI tool adoption behaviors among preservice mathematics teachers (Falebita, 2024)	Observational and survey study on AI usage among preservice teachers	Moderate adoption rates noted; adoption affected by teacher confidence, perceived usefulness, and institutional support mechanisms.

Conclusion

The studies demonstrated that artificial intelligence (AI) adoption in mathematics education has a largely positive impact on student achievement, engagement and teacher effectiveness. Incorporating AI into teaching and learning enhanced students' digital competencies and retention, while also improving academic outcomes. Similarly, AI tools like ChatGPT enabled personalized instruction that deepen students' conceptual understanding and boost engagement for better learning performance. These studies affirmed that AI not only benefits students but also strengthens teachers' instructional abilities, particularly when AIs are integrated thoughtfully into

mathematics classrooms. At the same time, teachers' attitudes, perceptions and readiness are important factors influencing AI adoption. While teachers generally hold positive views about AI's potential for enhancing mathematics teaching, challenges of limited infrastructure, insufficient training and lack of resources persist. Trust in AI technologies would play important role if aligned with factors like teaching experience and gender moderating willingness to adopt AI. Furthermore, barriers linked to anxiety and confidence issues among preservice teachers emphasize the importance of professional development and support systems to foster successful AI integration. Addressing these emotional, technical and systemic challenges will scale-up AI adoption in mathematics education. The importance of targeted training, mentoring and institutional support to build teachers' confidence, competence and trust in AI tools cannot be enough emphasised. Moreover, infrastructural improvements and equitable access to technology are vital to remove adoption barriers. While AI holds significant promise to transform mathematics teaching and learning, its full potential would be realized only through strategic efforts that support educators emotionally, technically and institutionally.

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DEVELOPMENT OF AN IMPROVED HOUSE PRICE PREDICTION MODEL BASED ON MACHINE LEARNING TECHNIQUES: A PROPOSED FRAMEWORK

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Abstract

The real estate sector is a vital driver of economic development, influencing household wealth, investment decisions, and broader financial stability. Accurate house price prediction is essential for buyers, sellers, developers, policymakers, and financial institutions, as mispricing can result in poor investments, discriminatory lending, and policy inefficiencies. Traditional valuation methods, such as expert appraisals and comparative market analysis, often face limitations of subjectivity, data inconsistency, and scalability. Recent advances in machine learning provide an opportunity to enhance predictive accuracy by leveraging diverse datasets and complex feature interactions. This study investigates the application of machine learning models in house price prediction, with emphasis on supervised learning approaches and ensemble methods. Key predictive features include location, property size, structural attributes, and socio-economic indicators. The research evaluates model performance using metrics such as precision, recall, root mean square error (RMSE), and mean absolute error (MAE). Findings are expected to demonstrate that machine learning models outperform traditional valuation approaches, offering higher accuracy, adaptability, and scalability. The outcomes of this research contribute to improved decision-making in real estate transactions, investment strategies, and housing policy formulation. Furthermore, the study highlights the role of machine learning in addressing challenges of data heterogeneity, feature complexity, and market dynamics, ultimately supporting sustainable urban development and financial stability.

Keywords: *House price prediction, machine learning, real estate valuation, predictive modeling, property pricing.*

Introduction

The real estate sector is a major contributor to national economies, impacting both individual wealth and broader economic stability. From housing affordability debates to investment strategies, accurate house price prediction holds central significance for diverse stakeholders, including homebuyers, sellers, real estate developers, investors, agents, policymakers, insurers, and financial institutions (D'Amato & Kauko, 2021; Kim & Kwak, 2024). Property values have broader consequence, influencing urban development, housing policy, and even macroeconomic stability. Inaccurate property price estimates can lead to misinformed investments, discriminatory lending, with potentially destabilizing effects on both households and national economies (Almajed *et al.*, 2025).

Recent research on house price prediction has largely centered on comparing the performance of various machine learning models, such as Random Forest, XGBoost, and deep learning techniques. While these studies offer valuable insights into the accuracy of different algorithms, they often end

at identifying the best-performing model based on metrics like RMSE or R^2 . However, emerging evidence, including findings by Almajed *et al.* (2025), has revealed that these high-performing models can exhibit bias linked to protected attributes such as race, and ethnicity. Such biases can lead to unfair property valuations, disproportionately affecting marginalized communities and perpetuating social and economic inequalities.

Literature Review

We critically analyze the foundational concepts, established methods, prevailing challenges, and related research concerning house price prediction. For instance, Almajed *et al.* (2025) studied racial and ethnic bias in ML-driven house price prediction in San Antonio, Texas. They found that despite unbiased ground truth, models exhibited varied bias levels, and in-processing mitigation techniques were more effective. The work importantly addresses fairness, a critical factor in equitable housing. A key limitation noted was fairness remains difficult to quantify fully across all subgroups.

Ouyang (2024) investigated house price prediction using multiple linear regression and Random Forest. The study demonstrated that while Random Forest improved accuracy by capturing nonlinear relationships better than linear regression, it still struggled with specific prediction errors on outlier properties. A key limitation noted was the challenge of interpreting complex ensemble models, which might reduce transparency for stakeholders relying on these predictions. The study highlighted the trade-off between model complexity and explainability in real estate valuation.

Application of Machine Learning-Based Methods in House Price Prediction

Machine learning (ML) methods have gained significant prominence in automated house price prediction due to their robust ability to model complex nonlinear relationships and interactions among diverse property and neighborhood features. These techniques are valued for their high predictive accuracy and scalability in processing large and heterogeneous real estate datasets.

Basic ML methods widely employed for house price prediction include; Decision Trees and Ensemble Methods (Algorithms like Random Forest, Gradient Boosting Machines, and XGBoost) are especially popular for their strong performance. These ensemble techniques combine multiple decision trees to model nonlinearities and feature interactions effectively, often outperforming traditional regression approaches in accuracy metrics such as RMSE and R^2 . Their interpretability through feature importance measures also supports understanding model decisions (Harshita *et al.*, 2025).

Metrics for Measuring House Price Prediction

Metrics commonly used for measuring the performance of house price prediction models focus on quantifying how closely the predicted prices match actual sale prices and how well the model explains price variability. The key evaluation metrics include; Root Mean Squared Error (RMSE), Mean Absolute Error (MAE), R-Squared (R^2) or Coefficient of Determination, Mean Squared Error (MSE).

Research Design of an improved house price prediction

This study adopts an experimental design aimed at developing, evaluating, machine learning models for house price prediction. This approach facilitates objective measurement of model

performance through statistical analyses, and controlled experimentation with various algorithms and datasets

i. Design an improved house price prediction conceptual framework:

Designing an improved house price prediction conceptual framework involves creating a comprehensive, systematic architecture that integrates data collection, processing, modeling, fairness assessment, and interpretability to enhance both the accuracy and equity of machine learning (ML) predictions in a real estate context.

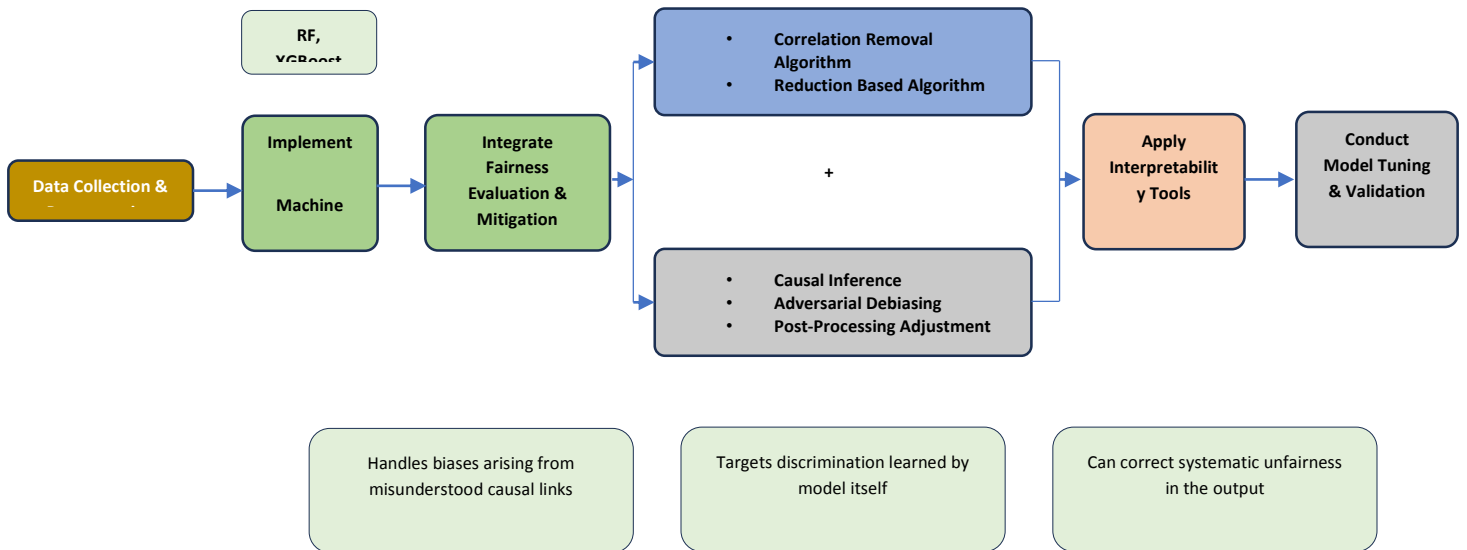


Figure 3.1: Conceptual framework of the proposed design of House Price Prediction

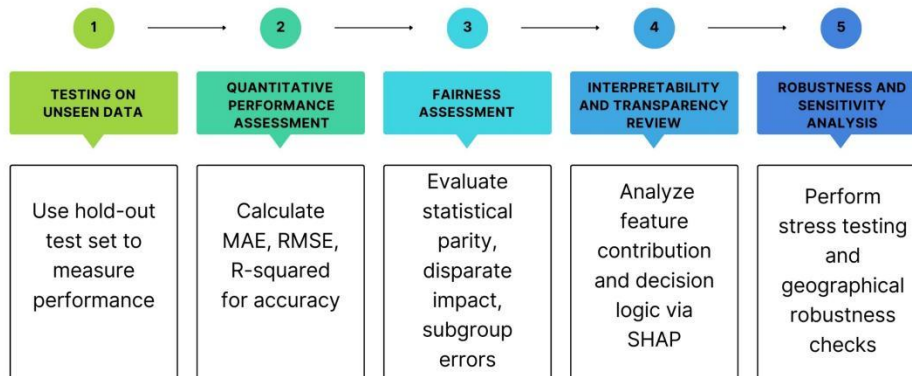
ii. Implement the design framework in objective (i) for house price prediction model:

Implementing the design framework outlined in the first objective involves translating the conceptual architecture into a practical and operational house price prediction model system. This phase focuses on implementing each component of the previously designed framework with attention to data integration, model training, fairness evaluation, and interpretability, ensuring a seamless and effective predictive pipeline.

Evaluate the developed prediction model in objective (ii):

Evaluating the developed house price prediction model, as specified in the third objective, involves a comprehensive and systematic assessment of both predictive performance and fairness metrics to ensure the model's effectiveness, reliability, and ethical suitability within real estate valuation contexts. This evaluation phase is a critical part of the overall architecture, serving as the validation checkpoint that verifies the success of the design and development efforts detailed in objectives (i) and (ii).

EVALUATION OF THE DEVELOPED MODEL



The evaluation process begins by partitioning the data into testing sets that were not used during model training or tuning, to provide an unbiased measure of the model's generalization ability. Key predictive performance metrics such as Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), and R-squared (R^2) are computed to quantify the model's accuracy in estimating property prices. These metrics offer insight into how closely the predictions align with actual sale prices, which is essential for practical applicability.

Parallel to accuracy assessment, the model undergoes fairness evaluation to detect and quantify any discrimination or bias affecting different demographic or socio-economic subgroups. Common fairness metrics such as statistical parity difference, disparate impact ratio, and subgroup prediction error disparities are leveraged to understand equity implications. This dual focus ensures that the model's high predictive performance does not come at the expense of fairness.

Conclusion

This research aims to develop an improved house price prediction model based on machine learning techniques. This study demonstrates the potential of machine learning techniques in improving the accuracy and reliability of house price prediction compared to traditional valuation approaches. By leveraging diverse features such as location, property attributes, and socio-economic factors, the models are able to capture complex, nonlinear relationships within real estate markets. The results highlight that machine learning not only enhances predictive performance but also offers scalability and adaptability across different housing contexts. These outcomes are significant for real estate investors, policymakers, financial institutions, and other stakeholders

who rely on accurate pricing for decision making. Future research could focus on integrating larger datasets, incorporating unstructured data such as images and text, and exploring advanced deep learning architectures to further refine prediction accuracy. The proposed framework target to reducing bias in valuation models and can improve access to housing finance and economic opportunities for marginalized groups, helping to combat systemic inequalities in the housing market. Overall, machine learning provides a robust framework for advancing data-driven solutions in real estate management and policy development.

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ASSESSMENT OF OCCUPANTS' LEVEL OF FACILITIES AND SERVICES SATISFACTION IN THE RESIDENTIAL HOUSING ESTATES BUILT ENVIRONMENT IN LOKOJA, KOGI STATE

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Abstract

The study assessed residents' satisfaction with facilities and services in public housing estates in Lokoja, Kogi State. Guided by two research questions and two null hypotheses, a descriptive survey design was employed. The target population comprised 2,820 residents from fifteen public housing estates. Due to the large sample size, a multistage sampling method was employed. Initially, the estates were stratified by factors such as location and population density. From these strata, eight estates were randomly selected to ensure diversity. Within these estates, 453 residents were chosen through simple random sampling. Data were gathered using a structured questionnaire, validated by experts from the Federal University of Technology, Minna, and pilot-tested in Talba estate, Niger State. The questionnaire's reliability was confirmed with a Cronbach's Alpha of 0.80. Data analysis, performed using SPSS version 26, involved calculating means and standard deviations for the research questions and z-tests for hypotheses at a 0.05 significance level. Results showed moderate satisfaction with both facilities (mean = 3.12) and services (mean = 2.86). The study recommended that estate management in Lokoja implement regular maintenance and upgrades to improve resident satisfaction. Additionally, it suggested establishing an active service response team with accessible contact information to facilitate effective communication and timely maintenance responses. These recommendations aim to enhance resident quality of life and the overall functionality of the housing estates.

Keywords: *Occupants, Facilities and Services, Satisfaction, Residential Housing Estates, Built Environment*

Introduction

The built environment and the quality of residential facilities and services have a profound impact on occupants' satisfaction and overall quality of life. As such, they are crucial considerations in urban planning, architecture, and real estate development. According to the United States Environmental Protection Agency (USEPA, 2022), the built environment encompasses all aspects of human life, including residential buildings, infrastructure for water and electricity, transportation systems, waste management, security measures, and recreational facilities. These elements significantly influence the comfort and satisfaction of residents. The built environment consists of man-made or modified spaces for living, working, and recreation, requiring substantial material resources to create. The impact of the built environment can be both positive, such as increased safety and productivity, and negative, like air pollution and reduced health quality.

Housing is a basic human need, on par with food and clothing, and serves as a key indicator of an individual's standard of living and societal status. Ensuring the provision of satisfactory housing that meets government standards and aligns with user needs and expectations has always been a

priority for both public and private housing sectors in Nigeria (National Housing Policy, 2022). In building projects, various services are interdependent and essential, emphasizing the importance of architectural, engineering, and construction expertise, particularly in urban areas. Lokoja, a rapidly growing urban center, is experiencing increased demand for housing due to population growth. Consequently, housing estates have been developed to meet this demand, but concerns remain about the quality of these estates and resident satisfaction with the provided facilities and services (Hassan *et al.*, 2023). As Okafor (2016) notes, housing is a fundamental human need that significantly impacts health, welfare, and productivity across all socioeconomic groups.

Occupants' satisfaction in residential housing estates refers to the contentment residents feel regarding the quality and effectiveness of the facilities and services provided in their living environment (Simeon *et al.*, 2022). This satisfaction encompasses various aspects, including the physical structure (space, noise control, lighting, ventilation), the availability and reliability of utilities (electricity, water, internet connectivity), and communal facilities and services (parking, security, green spaces, waste management, and recreational amenities). Resident satisfaction or dissatisfaction profoundly affects their comfort, well-being, and overall quality of life. Satisfaction is highly subjective, shaped by individual expectations and experiences, and is influenced by multiple factors such as cultural expectations, personal preferences, and social dynamics.

Understanding occupants' satisfaction levels is essential for urban planners, developers, and policymakers. It provides valuable insights for improving residential design, facility management, and housing policies, thereby enhancing residents' living conditions. Feedback on occupant satisfaction can inform better housing design practices, estate management strategies, and policy formulation aimed at improving urban living conditions. Resident satisfaction is an important area of study for professionals seeking to enhance the quality of life in residential areas (Parkes *et al.*, 2022).

Wang and Wang (2020) highlight the importance of infrastructural facilities and services in ensuring the proper functioning and utilization of residential properties. The demand for these facilities extends beyond the physical structure to include additional installations and fittings that enhance their utility. In residential properties, satisfaction includes shelter, protection, comfort, convenience, health, privacy, and dignity. A decent housing unit must meet the economic, physical, and environmental needs of its occupants. Economic satisfaction, or getting value for rent paid, may be unrealistic if physical satisfaction, which includes uninterrupted power supply, water supply, and waste disposal, is not adequately addressed. Environmental satisfaction, encompassing social status and neighborhood security, also contributes to the perceived utility of residential properties.

Statement of the Problem

Residential housing estates in Lokoja are designed to provide a satisfactory living environment, offering essential facilities and services such as water supply, electricity, waste management, and recreational spaces. However, inadequate planning and maintenance have resulted in issues like structural deterioration, plumbing problems, electrical faults, and overall degradation of the living environment. According to David *et al.* (2023), residents have expressed concerns over unreliable water and electricity supply, poor waste management, inadequate security, and the lack of recreational facilities. Furthermore, aspects related to the built environment, including housing design, construction quality, integration with the natural environment, and neighborhood layout,

are often neglected in planning, construction, and maintenance, despite their significant impact on residential satisfaction.

Without a comprehensive understanding of the factors influencing satisfaction with facilities and services, it is difficult for architects, urban planners, and policymakers to develop effective solutions to improve living conditions. This study aims to assess residents' satisfaction with the facilities and services provided in the residential housing estates in Lokoja, Kogi State, to better inform future planning and policy decisions. Understanding these key issues is crucial for enhancing the quality of life in these estates and ensuring that housing developments meet the needs and expectations of their occupants.

Purpose of the Study

The following are the purpose of the study

1. Identify the level of occupant's satisfaction with the facilities provided in the residential housing estates in Lokoja, Kogi State..
2. Determine the level of occupants' satisfaction with the services provided in residential housing estates in Lokoja, Kogi State.

Research Questions

The following research questions guided the study:

1. What is the level of occupants' satisfaction with the facilities provided in the housing estates in Lokoja, Kogi State?
2. What is the level of occupants' satisfaction with the services provided in housing estates in Lokoja, Kogi State?

Research Hypotheses

The following null hypotheses were formulated to guide the study and was tested at 0.05 level of significance.

1. **H₀₁:** There is no significant difference in the mean responses of new and old occupants of residential housing estates as regards the level of occupants' satisfaction with facilities provided in the residential housing estates in Lokoja, Kogi State.
2. **H₀₂:** There is no significant difference in the mean responses of new and old occupants of residential housing estates as regards the level of occupants' satisfaction with the services provided in the residential housing estates in Lokoja, Kogi State.

Research Methodology

This study adopted descriptive survey research design. The study was conducted in Kogi State. Kogi State is located in the central region of Nigeria (North-Central). The target population of the study was 2820 old and new housing residents living in the fifteen (15) public housing estates in Lokoja, Kogi State. A multistage sampling technique was used for the study to select 8 public housing estate in Lokoja. A 30-items structured questionnaire was used as the instrument for data collection. The questionnaire was designed in line with the research questions, and structured on a five-point rating scale. The structured questionnaire was validated by three (3) experts from the Department of Industrial and Technology Education, Federal University of Technology Minna, The experts were asked to go through the instrument and make suggestions where necessary. In

order to determine the reliability coefficient of the instrument, a pilot study was conducted in Talba housing estate in Minna Niger State using 20 residents from the housing estate. The total of 453 structured questionnaires was administered to the respondents in the eight sampled housing estates with the help of four (4) research assistants. Mean and standard deviation were used to answer the research questions while z-test was used to test the null hypotheses at 0.05 level of significance. Real upper and lower limit of numbers was used in order to determine the level of agreement or disagreement of the respondents to the items. Statistical Package for the Social Sciences (SPSS version 26) was used for data analysis. The decision on each item of the research questions was based on the resulting mean scores interpreted relatively to the concept of real lower and limits of numbers as shown in Table 3.4. Furthermore, the decision to reject or retain the null hypothesis was based on the obtained p-value. If the p-value was less than or equal to 0.05 ($p \leq 0.05$), there was statistically significant evidence to reject the null hypothesis. If the p-value was greater than 0.05 ($p > 0.05$), the null hypothesis was retained.

Results

Research Question 1

What is the level of occupant's satisfaction with the facilities provided in the housing estates in Lokoja, Kogi State?

The data for answering research question one is presented in Table 1.

Table 1: Mean and Standard Deviation of Respondents on the Level of Occupants' Satisfaction with the Facilities Provided in the Housing Estates in Lokoja, Kogi State.

S/N	Items	Mean ($\bar{x}$) N = 362	SD	Remark
1	Backup generators for constant supply of electricity	3.48	0.70	ML
2	Boreholes for constant water supply	3.20	0.45	ML
3	CCTV surveillance systems	2.48	0.59	LL
4	ATM facilities	3.42	0.69	ML
5	Paved roads	3.43	0.91	ML
6	Recreational centres	3.35	0.70	ML
7	Internet and cable TV infrastructure	3.19	0.81	ML
8	Shopping complex	3.39	0.70	ML
9	Car parking space	3.30	0.55	ML
10	Waste management systems	3.29	0.64	ML
11	Landscaped gardens	3.18	0.78	ML
12	Healthcare centre	2.48	0.68	LL
13	Street lighting	2.40	0.78	LL
14	Fitness centre	3.35	0.68	ML
15	Firefighting equipment	2.88	0.75	LL
	Grand Mean/SD	3.12	0.68	Moderate

Key: N = Number of respondents; SD = Standard Deviation; ML = Moderate Level; LL = Low Level

Table 1 shows the mean responses of the respondents on 15 items posed to determine the levels of occupants satisfaction with the facilities provided in the housing estates in Lokoja, Kogi State with a grand mean of 3.12. This implies that the level of occupants' satisfaction with the facilities provided in the housing estates is moderate. The standard deviation of the items ranged from 0.45 to 0.81 which implies that the 15 items had their standard deviation less than 1.96. This indicates that the respondents were not too far from the mean and were close to one other in their responses. This closeness of the responses adds value to the reliability of the mean. Hence, the occupants have moderate level of satisfaction with facilities provided in the housing estates.

Research Question 2

What is the level of occupants satisfaction with the services provided in housing estates in Lokoja, Kogi State?

The data for answering research question two is presented in Table 2.

Table 2: Mean and Standard Deviation of Respondents on the Level of Occupants' Satisfaction with the Services Provided in the Housing Estates in Lokoja, Kogi State

N = 362

S/N	Items	Mean ($\bar{x}$)	SD	Remark
1	Security	3.35	0.52	ML
2	Electricity supply	2.48	0.48	LL
3	Water supply	2.40	0.50	LL
4	Waste disposal services	3.34	0.70	ML
5	Landscaping and gardening maintenance	3.35	0.44	ML
6	Road maintenance	3.40	0.60	ML
7	Internet and Wi Fi	2.49	0.54	LL
8	Health clinics	3.01	0.80	ML
9	Car wash services	2.44	0.55	LL
10	Laundry services	3.40	0.64	ML
11	Restaurant or cafes	3.20	0.66	ML
12	ATM facilities	2.28	0.68	LL
13	Schools or educational facilities	3.21	0.80	ML
14	Shuttle services	2.26	0.60	LL
15	Fitness centres or gyms	2.35	0.79	LL
Grand Mean/SD		2.86	0.62	Moderate

Key: N = Number of respondents; SD = Standard Deviation; ML = Moderate Level; LL = Low Level

Table 2 shows the mean responses of the respondents on 15 items posed to determine the level of occupants satisfaction with the services provided in the housing estates in Lokoja, Kogi State with a grand mean of 2.86. This implies that the level of occupants' satisfaction with the services provided in the housing estates is moderate. The standard deviation of the items ranged from 0.44 to 0.80 which further implies that the 15 items had their standard deviation less than 1.96 indicating that the respondents were not too far from the mean and were close to one other in their responses. This closeness of the responses adds value to the reliability of the mean. Hence, the occupants have moderate level of satisfaction with the services provided in the housing estates.

Hypothesis 1

There is no significant difference in the mean responses of new and old housing occupants as regards the level of occupants' satisfaction with facilities provided in the residential housing estates in Lokoja, Kogi State ($P < 0.05$). Null hypothesis one was tested and the result is presented in Table 3.

Table 3: Z-test Analysis Showing the Significant Difference between the Mean Responses of New and Old Housing Occupants' as Regards the Level of Occupants' Satisfaction with Facilities provided in the Residential Housing Estates in Lokoja, Kogi State

	<u>Levene's Test for Equality of Variances</u>		<u>Z-test for Equality of Means</u>						
	<u>F</u>	<u>Sig.</u>	<u>Z</u>	<u>Df</u>	<u>Sig. (2- tailed)</u>	<u>Mean Diff.</u>	<u>Std. Error Diff.</u>	<u>95% Confidence Interval of the Difference</u>	
								<u>Lower</u>	<u>Upper</u>
<u>Equal variances assumed</u>	11.240	.520	3.845	360	.034	.64740	.06842	.09128	.40820
<u>Equal variances</u>			2.726	24.020	.152	.64740	.08502	.07580	.38082
<u>Facilities Provided</u>									
<u>not assumed</u>									

($p > 0.05$) SD = Significance Difference

Table 3 shows the z-test analysis for the test of significant difference between the mean responses of new and old housing occupants as regards the level of occupants' satisfaction with facilities provided in the residential housing estates in Lokoja, Kogi State. The Levene's test was carried out to determine equality of variance. The test showed an F value of 11.24 with a p-value of 0.52 which shows that equal variances was assumed. Also, the z-test analysis showed a z-value of 3.85 and a p-value of 0.03 which is less than the bench mark of 0.05. This implied that there was significant difference between the mean responses of new and old housing occupants as regards the level of occupants' satisfaction with facilities provided in the residential housing estates in Lokoja, Kogi State. Hence null hypothesis one was rejected.

Hypothesis 2

There is no significant difference in the mean responses of new and old housing occupants as regards the level of occupants' satisfaction with the services provided in the residential housing estates in Lokoja, Kogi State ($P < 0.05$). Null hypothesis two was tested and the result is presented in Table 4.

Table 4: Z-test Analysis Showing the Significant Difference between the Mean Responses of New and Old Housing Occupants As Regards the Level of Occupants' Satisfaction with the Services provided in the Residential Housing Estates in Lokoja, Kogi State

		Levene's Test for Equality of Variances		Z-test for Equality of Means						
		F	Sig.	Z	Df	Sig. (2- tailed)	Mean Diff.	Std. Error Diff.	95% Confidence Interval of the Difference	
Services Provided	Equal variances assumed	9.248	.075	3.890	360	.024	.52044	.05408	.08408	.35404
	Equal variances not assumed			2.735	24.100	.098	.52044	.08740	.04822	.39805

(p>0.05) SD = Significance Difference

Table 4 shows the z-test analysis for the test of significant difference between the mean responses of new and old housing occupants as regards the level of occupants' satisfaction with the services provided in the residential housing estates in Lokoja, Kogi State. The Levene's test was carried out to determine equality of variance. The test showed an F value of 9.25 with a p-value of 0.75 which means that equal variances was assumed. Furthermore, the z-test analysis showed a z-value of 3.89 and a p-value of 0.02 which is less than the bench mark of 0.05. Hence, null hypothesis two was rejected. This implied that there was significant difference between the mean responses of new and old housing occupants as regards the level of occupants' satisfaction with the services provided in the residential housing estates in Lokoja, Kogi State.

Findings of the Study

The following findings emerged from the study based on the research questions answered and the hypotheses tested.

1. The level of occupants' satisfaction with the facilities provided in the housing estates in Lokoja, Kogi State was moderate.
2. The level of occupants' satisfaction with the services provided in the housing estates in Lokoja, Kogi State was moderate.
3. There was significant difference between the mean responses of new and old housing occupants as regards the level of occupants' satisfaction with facilities provided in the residential housing estates in Lokoja, Kogi State.
4. There was significant difference between the mean responses of new and old housing occupants as regards the level of occupants' satisfaction with services provided in the residential housing estates in Lokoja, Kogi State.

Discussion of Findings

The findings of research question one revealed that occupants' satisfaction with facilities in Lokoja's housing estates was moderate. Facilities assessed included backup generators, boreholes, CCTV systems, recreational centers, parking spaces, paved roads, street lighting, and firefighting equipment. A significant difference in satisfaction levels was observed between new and old housing occupants. This difference likely result from the degradation of facilities in older residences compared to the generally better condition of facilities in newer properties.

The findings align with previous research indicating moderate satisfaction levels among residents in various locations: Abiodun and Kingsley (2020) in Benin City, Faisal (2023) in Hamad City, and Elahi (2024) in Mashhad. However, they differ from Ogbuefi and Okoro (2019), which reported high satisfaction in private housing estates in Port Harcourt, potentially due to the superior management by private developers in those estates.

The findings on research two revealed that the level of occupants' satisfaction with the services provided in the housing estates in Lokoja, Kogi State was moderate. The services include: security, electricity supply, water supply, waste disposal services, landscaping and gardening maintenance, road maintenance, internet service and wifi, health clinics and car wash services among others. Also, the findings on hypothesis two revealed that there was significant difference between the mean responses of new and old housing occupants as regards the level of occupants' satisfaction with services provided in the housing estates in Lokoja, Kogi State. This implied that the respondents had different opinions regarding the level of their satisfaction with the services provided in the housing estates. This could be as

The findings align with several studies indicating moderate satisfaction levels with housing services: Azian *et al.* (2023) in Kenya, Abiodun and Kingsley (2020) in Benin City, and Faisal (2023) in Gaza Strip. They also confirm Ogbuefi and Okoro's (2019) finding of significant differences in satisfaction between private and public housing estate occupants. However, they contrast with Ogbuefi and Okoro's (2019) observation that private estate occupants in Port Harcourt reported high satisfaction, likely due to the superior facilities and services provided by private developers.

Conclusion

The study concluded that while essential facilities like backup generators, boreholes, CCTV systems, and street lighting are present, overall occupant satisfaction is only moderate. This suggests that the infrastructure, though in place, does not fully meet occupants' needs, with notable differences in satisfaction between new and old housing occupants. The moderate satisfaction with services such as security, electricity, water supply, and waste disposal indicates that these services also fall short of fully meeting occupants' needs. The disparities in satisfaction levels emphasize the need for targeted improvements, especially in older estates where facilities may be outdated or inadequate.

Recommendations

The following recommendations were made based on the findings of this study;

1. The management of housing estates in Lokoja, Kogi State should periodically carry out routine maintenance and general upgrade of existing facilities to improve the level of occupants' satisfaction with their facilities.
2. The management of the housing estates in Lokoja, Kogi State should establish an active service response team and their contact should be distributed to all occupants in the estate to enable effective communication and prompt response for cases of emergency.
3. The management of housing estates in Lokoja, Kogi State should create avenues such as suggestion boxes, social media platforms (Whatsapp group) and help lines where occupants will have the opportunity to share the challenges they face and necessary arrangement be made to address such challenges.

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EFFECTS OF DUAL MODES COMPUTER MODULE ON ELECTRONIC DEVICE AND APPLICATION ACHIEVEMENT AND RETENTION IN NORTHERN NIGERIAN UNIVERSITIES.

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Abstract

The study examined the effects of Dual modes computer module on Electronic Device Achievement and retention in Northern Nigerian Universities, this study adopted a pretest-posttest experimental design, two research question and two hypotheses guided the study and a sample of 75 level three hundred students from Bayero University and Abubakar Tafawa Balewa University. The students that were taught using Instructors Based Computer Module (IBCCM) are experimental group while those taught using demonstration Method are control group the data was collected using Electronics Devices Achievement Test (EDAT) and Electronics Devices retention Test (EDRT) as instrument. A trial test was carried out and a reliability coefficient of 0.87 was obtained using Pearson Product Moment Correlation Coefficient. Mean and standard deviation was use to answer the research questions and t-test was used to test the hypothesis. The study revealed that, there were significant differences in post-test mean score of IBCCM as compare to that of demonstration Method. Based on these findings, it was therefore recommended that Electronic Devices and Application lecturers should be encouraged to use instructor's Based computer module for effective and meaningful teaching and learning.

Keywords: *Instructors based computer module; Student's based computer module and dual modes*

Introduction

Education is a general term which refers to an exercise that engages everyone. It is a process of enabling individuals to live as useful and acceptable members of a society. Different categories of education are available among which technical and vocational education is included. Umar (2022) defined technical education as the type of education that facilitates the acquisition of practical and applied skills as well as basic scientific knowledge. The Objectives of Technical and Vocational Education stresses the acquisition of knowledge relevant to employment; it emphasized the demonstrable of specific skills and competencies in individuals. Their main objective is to provide students with the skills and knowledge necessary for vocational capabilities and entry into job content (Okoye and Maxwell, 2016). According to Umar (2022) pointed out that technical education makes a significant contribution in areas such as, metal work technology, mechanical/automobile technology, building technology, woodwork technology and electrical and electronics technology among others

Electrical Electronics Technology as a branch of technology education has been defined according to Odudu and Edidiong (2024) as that aspect of technology education which deals primarily with electricity and principles of magnetism and devoted to the utilization of forces of nature and materials as well as studies of semiconductors materials and their behaviours for the benefits of mankind. They further opined that the technical and vocational training centres need to provide conducive learning environments for improve students' academic achievement.

Academic achievement is based on the degree of intellectual stimulation that the child could receive from learning situation to achieve is to accomplish or gain by effort or do something successful with an effort and skill (Owobamigbe, Usman & Oguche, 2025). Egya, Uzoechi and fatokum (2016) pointed out that students' achievement is dependent on several factors among which are learning environment and instructional methods. Teachers with good teaching strategy challenge students to work at higher intellectual level, attain sound academic achievement and better knowledge retention.

Retention is an individual's ability to remember and recall learned information, materials and experience over a time. Retention can also be defined as the process of maintaining the available new meaning or part of them. Human memory is imperfect and fragile as a result periodic review is required for the long-term retention of knowledge, skill and information. Learning outcome of every student, largely depends on the type of teaching methods, teaching strategies and instructional techniques or approaches employed by the teacher during instruction. One of the major aims of technical education is the acquisition of appropriate skills by individuals to live and as well contribute meaningfully to the development of the society. (Medugu, Zakari, isyaku and Umar 2023) Bakare, (2009). pointed out that Traditional teaching methods such as lecture, demonstration and field trip adopted for teaching electronics devices and application in our universities by most of the lecturers are often referred to as conventional teaching method termed to be teacher centred instead of student's centre. This method of teaching technical subjects discouraged creativity and disallowed students from thinking beyond what is presented to them by their teachers. The students are considered as passive learners and as a result become apathetic and repulsive to learning. Therefore, this study will determine the combine effect of Computer module on electrical/electronic technology education students' academic achievement and retention in Electronics Devices and application.

Objectives of the study

The main purpose of the study is to investigate the effect of Dual modes computer module on students' achievement and retention in Electronics Devices and Application in Northern Nigerian Universities. Specifically, the study intends to:

1. Determine the effect of instructor-based computer complete module on students' achievement in electronics devices and application in northern Nigerian Universities
2. Determine the effect of instructor-based computer complete module on students' retention in electronics devices and application in northern Nigerian Universities

Research Questions

The following research questions were set guide the study:

1. What is the the effect of instructor-based computer complete module on students' achievement in electronics devices and application in northern Nigerian Universities?
2. What is the effect of instructor-based computer complete module on students' retention in electronics devices and application in northern Nigerian Universities

Research Hypotheses

The following null hypotheses were formulated and tested at 0.05 alpha values.

Ho₁: There is no significant difference between the mean achievement score of students in electronic devices and application taught using instructed-based computer complete module and conventional approach in northern Nigerian Universities

Ho₂: Ho₃: There is no significant difference between the mean retention score of students in electronic devices and application taught using instructed-based computer complete module and conventional approach in northern Nigerian Universities

Methodology

The study utilized pre-test, post-test quasi-experimental and control group design. The study has two group; experimental (EG) and control (CG). Before treatment, the two group were pre-tested (O1) to ensure selection of university with comparative abilities. The experimental group were taught using instructor-based computer module for a period of six weeks. Control group were taught using traditional lecture method. The two groups were post-tested (O2) using the same instruments in pre-test. The population for this study consists of all level three students offering electronic device and application. The sample of this study covered a total number of 75 level three students selected from two public university offering electronic devices and application in the study area. The two universities are Bayero University, Kano and Abubakar Tafawa Balewa University, Bauchi. The choice of 75 students is in line with central unit theorem which prescribe that minimum of 30 participants is adequately enough to form a sample in an experimental study of this nature. In each University intact class of level three were sampled and used for the study. Data collection procedures begin with introducing the researcher and research assistants to universities to be used in the study by means of introductory letter. Immediately after introduction, the researcher explains to the respondents the purpose of the study and the need for cooperation. Pretest was then administered before treatment. The treatment is teaching experimental group using Instructor- based teaching approach, while control group were exposed to lecture method. The procedure for the research treatment is six weeks. The data collected were subjected to analysis, the research questions were answered by using Mean and Standard Deviation. The hypotheses were tested using t test in SPSS Package.

Results

Research Question One:

What is the effect of instructor-based computer module on students' achievement in electronics devices in northern Nigerian Universities?

The result of data presented in Table 1 showed that the mean gain score of instructor-based Computer module approach is higher than that of conventional method. From the array of the mean gain scores, we have IBCM = 40.466 while the conventional method is = 17.200 with this result, the IBCM has academic achievement mean score higher than the academic achievement mean score of students in the conventional method group. Therefore, using instructor-based computer module approach of instruction is more effective than the conventional method of instruction in improving the academic achievement of students in electrical and electronic Technology.

Table 1: Mean and standard Deviation of Achievement Scores of Electrical and Electronic Technology Education Students taught using instructor-based computer module (IBCM) and those taught using conventional Teaching approach.

Method	N	Pretest		Post-test		Gain score
		X ₁	SD ₁	X ₂	SD ₂	
IBCMA	50	19.0667	4.6670	59.5333	7.1800	40.4666
Conv.	25	14.0667	3.7314	31.2667	3.3693	17.2000

Research Question Two:

Determine the effect of instructor-based computer module on students' retention in electronics devices in northern Nigerian Universities.

The result of data presented in Table 2 showed that the mean gain score of instructor-based computer module approach is higher than that of conventional method. from the mean gain score we have IBCMR = 35.2000 whilst the conventional method is = 21.9333 This result indicates that the IBCM instructional approach is more effective on the post mean gain Retention scores of students in Electrical and Electronic Technology.

Table 2: Mean and standard Deviation of retention score of Electrical/Electronic Technology taught using instructor-based computer module IBCM and conventional teaching approach.

Method	N	Postposttest	
		X ₁	SD ₁
IBCMR	50	35.2000	5.7475
Conv.	25	21.9333	3.5550

Hypothesis One:

H₀₁: There is no significant difference between the mean achievement score of students in electronic devices taught using instructor-based computer module and conventional approach in northern Nigerian Universities

The result of data presented in Table 3 showed that there is a statically significant difference between the mean achievement score of Electrical/Electronic Technology students taught using IBCM and conventional teaching method, t (28) 13.80, P = 0.02. This therefore suggests that the null hypothesis is rejected.

Table 3: Independent Sample t-test of student's achievement score in Electrical and Electronics Technology taught using instructor-based computer module IBCM and conventional method

S/N	Group	N	X	SD	df	T	P-Value	Remarks
1	IBCM	50	59.5333	7.1800	28	13.80	0.02	S
2	Conv.	25	31.2667	3.3693				

S=Significance<0.5, df=28

Hypothesis Two:

H₀₂: There is no significant difference between the mean retention score of students in electronic devices and application taught using instructed-based computer module and conventional approach in northern Nigerian Universities

The result of data presented in Table 4 showed that there is a statically significant difference between the mean achievement score of Electrical / Electronic Technology students taught using IBCM and conventional teaching method, $t(28) 7.603P = 0.011$ this therefore suggests that the null hypothesis is rejected.

Table 4: Independent Sample t-test of student's Retention score in Electrical and Electronics Technology taught using instructor-based computer module IBCM and conventional method

S/N	Group	N	X	SD	df	T	P-Value	Remarks
1	IBCMR	32	35.2000	5.7475	28	7.603	0.0114	S
2	DEMR	26	21.9333	3.5550				

S=Significance<0.5, df=28

Discussion of the findings

The major finding of this research here revealed that, the achievement mean score of students taught Electronic Devices using Instructor-based Computer module approach was higher than the performance of students taught using conventional method. The aspect of this finding is in line with the findings of Samaila, Makinde and, Zambwa (2016), who reported that there was variation between the mean scores of students taught Electrical and Electronic Devices at N.C.E. II level using CAI and students taught using lecture method. It is also in agreement with the finding of Reagan (2017) who reported that students taught using Computer Aided Instructions (CAI) performed significantly better than those taught using conventional method. The hypothesis one also revealed that, there was a significant difference between the academic achievement scores of students taught Electronic Devices using instructor-based computer module and those taught the same concepts using conventional method this findings disagree with the findings of Wallace, sini and Abdulgafar (2021) conducted their study and reported that no significant difference found between the performance of JSS students taught Basic Technology with CAI and those taught with traditional method.

Additionally, the mean gain retention score of students taught Electronic Devices and application using Instructor-based Computer module approach was higher than the mean gain retention score

of students taught using conventional method. This finding is similar to the findings of study conducted by Ogo and Nelson (2023) who's finding revealed that E-content instructional strategy happens to be more effective for enhancing retention ability of unity college students in Building construction than conventional lecture method. The test of hypothesis here reveal that there is a significant difference between the mean retention score of students in electronic devices and application taught using instructed-based computer module and conventional approach in northern Nigerian Universities this is also in line with the finding of Ogo and Nelson (2023) who's finding revealed that There was a significant difference between the mean retention score of students taught building construction using the e-content instructional strategy and those taught using the conventional lecture method

Conclusion

Application of computer technology to all aspects of human endeavor coupled with the need to create student-centered classroom to engage learners in their leaning tasks, improve learners' interest and consequently achievement, the University subjects has necessitated the use of computer in teaching. This study has found out that Computer module improved students' achievement and retention in electronics devices and application than the conventional teaching methods. when Computer module is used for teaching. These results therefore revealed that Computer module is a viable alternative to the conventional teaching methods in teaching basic electronics. Moreover, Computer module provides powerful tools to support the shift to student-centered learning and is capable of creating a more interactive and engaging learning environment for teachers and learners.

Recommendations

Based on the findings and conclusion from this study, the following recommendations were made:

1. More attention should be accorded on computer literacy and operation in the University and relevant computer assisted instructional packages should be developed for use within the Nigerian universities systems.
2. Electrical/Electronic Technology Education lecturers should adopt the use of computer module to teach electronics devices and Application
3. Further empirical studies should be carried out on the use of computer for instructional purposes, on different subjects and at different levels to provide sound basis for the integration of computer in Nigerian Universities.
4. Curriculum planners though Nigeria University commission (NUC) should consider review of curriculum for electronic devices and application for university with a view to incorporating the computer module
5. Since the findings of this study showed that students who worked on the computer module performed better than those who worked on the conventional teaching method, students should be encouraged to develop interest in the use of computer.

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TEACHERS' AWARENESS, ADOPTION CONSIDERATIONS, AND CAPACITY NEEDS FOR UBEC'S STATION ROTATION MODEL WITHIN JUNIOR SECONDARY SCHOOLS IN GWAGWALADA AREA COUNCIL, FCT-ABUJA

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Abstract

The Universal Basic Education Commission (UBEC) in Nigeria advocates blended learning models like the Station Rotation Model (SRM) to address systemic educational challenges. However, successful implementation hinges on teacher readiness. This paper investigates Teachers' Awareness, Adoption Considerations, and Capacity Needs for UBEC's Station Rotation Model within Junior Secondary Schools in Gwagwalada Area Council, FCT-Abuja. The researchers raised three research questions on teachers' awareness, adoption considerations and capacity needs. The study utilizes the descriptive survey research design. The population of this study consists of all the teachers in secondary schools in FCT-Abuja. The target population of the study consists of all the junior secondary school teachers in FCT-Abuja. A sample of one hundred twenty (127) teachers were selected using the purposive and simple random sampling technique. The Teachers' Awareness, Adoption Considerations, and Capacity Needs for SRM Questionnaire (TAACCNCQ) was used for data collection. The instrument was subjected to expert judgement for face and content validity. The reliability of the instrument was determined using a pilot test of test-retest method and a reliability index score of $r=0.85$ was obtained using the PPMC. The findings revealed low awareness (65.3% unfamiliar with SRM structure), significant infrastructure gaps ($M=4.21$, $SD=0.76$), and high demand for digital training ($M=4.45$, $SD=0.69$). The study recommended amongst others that UBEC should intensify awareness efforts and provide targeted training to support the effective implementation of the station rotation model secondary schools in FCT-Abuja.

Keywords: UBEC, Station Rotation Model, Awareness, Adoption Considerations, Capacity Needs.

Introduction

Blended learning is an approach which integrates e-learning with all enhancements of technological devices with traditional learning to enhance classroom interaction (Daskan and Yildiz, 2020). Blended learning involves the use of ICT based facilities, gadgets, machines, equipment's, tools to complement the chalk-talk method for effective teaching and learning. Hence, it is considered a "blend" of both technology and conventional methods which provides flexibility, as learners and educators do not have to be at the same location at the same time. To ensure proper integration of technology and face-to-face teaching, there are many models of blended learning.

There are four major blended learning models as outlined by Larsari *et al.* (2023), these include the rotation models, flex model, A la Carte model and enriched virtual model. The rotation model provides a structure for students that are timetabled in a way that will meet many of their expectations from traditional educational delivery methods. As opined by Baquero and Escortell (2022), Station rotation models are categorized into station rotation, individual rotation, lab rotation, and flipped classroom models. These models vary from one another based on certain peculiarities that warrant their adoption, but their aim remains consistent; to integrate technology into the classroom in order to enhance students' learning outcomes. As outlined earlier, the station rotation model is one of these blended learning models that integrates technology and face-to-face teaching and learning. The station rotation model is a blended learning approach where students cycle among several classroom stations, at least one of which is a technology-based station. The Station Rotation Model, a versatile blended learning model where students rotate through different learning stations, including online and teacher-led activities

The Universal Basic Education Commission (UBEC) is the body saddled with the responsibility of basic education in Nigeria, and they have recommended the adoption of the station rotation model (Wali, 2023). In their modified station model, they designed three major stations constituting a teacher led station, ICT station and collaborative station. The learners are expected to cycle between these stations during the duration of a particular lesson, the teacher-led station is the phase where some learners are to interface with the teacher, and at the same time some learners are at the ICT station and others at the collaborative station. These learners' cycle through this station until the lesson ends. The station rotation model is reflected in the design and planning of the UBEC's smart schools across the 36 states in Nigeria including the Federal Capital Territory (FCT), Abuja. This model has shown to be effective and can maximise teachers' efficiency (Yukhymenko *et al.*, 2024) especially in resource constrained regions but how aware are the teachers as regards the station rotation model.

To be aware of something implies having knowledge of it, so awareness can be described as the state or capacity of an individual to identify, sense, or be conscious of objects, events, or sensory patterns (Gafoor, 2012). It implies teachers' knowledge or understanding of the station rotation model. Based on this, Mukherjee and Bhuyan (2023) revealed that majority of teacher educators are aware of blended learning. Similarly, Bhunia and Paul (2023) revealed that secondary school teachers were aware of blended learning. But notably both studies were not specific to the station rotation model and rather used an umbrella term, blended learning. Studies investigating teachers' awareness of station rotation model were scarce. The awareness of the station model is expected to yield substantial utilisation, therefore there is a need to ascertain teachers' level of adoption of the station rotation model.

Adoption is a term used to describe the process by which individuals and organizations accept and integrate new methods, ideas, pedagogies and technologies into their practices, influenced by factors such as innovativeness, compatibility, complexity, trialability, and observability (Al-kfairy *et al.*, 2024). The adoption of the station rotation model by teachers is dependent on many factors and based on the Technology Acceptance Model by Davis (1989) it can be summarised as the perceived usefulness and perceived ease of use. If the station rotation model is perceived to be of benefit for teachers, then there is a greater likelihood for the adoption and likewise if the model is considered too easy to use and manipulate. Examining the effectiveness of this model, Osuji and

Abraham (2024) revealed that students exposed to Station Rotation Model of teaching and learning performed better than those in the control group who were not exposed to Station Rotation model of teaching.

For teachers to adopt the SRM, there must be sufficient training in the form of continuous professional development. Echoing this, Vega-Bajana (2019) revealed that access to technology devices, sufficient training and creating a conducive classroom environment can influence the adoption of the SRM. Checking the level of adoption of the SRM, Polat (2020) revealed that elementary school teachers did not adopt blended learning as much as primary and secondary school teachers. This may be attributed to training received by these teachers and preference for child friendly teaching methodologies that do not involve technology usage. Another reason for this may be due to difficulty in ensuring that elementary pupils adhere to the rotational nature of the SRM. Thus, for the SRM to be adopted by teachers, then the teachers must have the required capacity to integrate it into their teaching and learning.

Capacity can be described as the state of being able to achieve or do something. It is the power to carryout tasks or do something. Based on this, Zhang and Stephens (2016), defined teacher's capacity as the ability of the teacher to understand and act on curriculum reforms. The author added that teacher capacity is described as professionally informed judgment and disposition to act. In order to be capable, teacher's needs must be met. Thus, teacher capacity refers to the collective knowledge, skills, attitudes, and professional ethics that enable teachers to perform effectively and meet the evolving demands of the education sector. Adetayo and Amede (2021) summarised these needs as ICT skills, creative skills and technical skills. In addition, specifically identified ability to organize online discussion, manage in person and online learning, online quizzes and discussion boards, online technologies for evaluation, technologies for special needs, the ability to create repositories for online and offline resources and the ability to effectively communicate using text, audio and video.

Statement of problem

The rising case of poor learning outcomes of students as observed by teachers has warranted the need for innovative approaches such as the station rotation Model (SRM). To counteract the negative impact of poor learning outcomes such as unemployment, kidnapping, armed robbery and other social vices; it is vital that the SRM is implemented but teachers must be able aware, consider the adoption and have then capacity to implement the model as recommended by UBEC for basic education in Nigeria. But unfortunately, findings have shown that there are very few studies that have investigated teachers' awareness, adoption considerations and capacity needs for the UBEC station rotation Model. It is based on this premises that this study intends to investigate teachers' awareness, adoption considerations, and capacity needs for UBEC's station rotation model within Junior secondary Schools in Gwagwalada Area Council, FCT-Abuja.

Research objectives

1. Determine the level of teachers' awareness towards the UBEC's station rotation model within Junior secondary Schools in Gwagwalada Area Council, FCT-Abuja
2. Investigate teachers' adoption considerations for UBEC's station rotation model within Junior secondary Schools in Gwagwalada Area Council, FCT-Abuja

3. Examine teacher's capacity needs for UBEC's station rotation model within Junior secondary Schools in Gwagwalada Area Council, FCT-Abuja.

Research questions

1. What is the level of teachers' awareness towards the UBEC's station rotation model within Junior secondary Schools in Gwagwalada Area Council, FCT-Abuja
2. What are teachers' adoption considerations for UBEC's station rotation model within Junior secondary Schools in Gwagwalada Area Council, FCT-Abuja
3. What are the teacher's capacity needs for UBEC's station rotation model within Junior secondary Schools in Gwagwalada Area Council, FCT-Abuja.

Methodology

The study adopted the descriptive survey research design. The population of this study consisted of all the teachers in junior secondary schools in FCT-Abuja. A sample of one hundred and twenty-seven (127) teachers was selected for the study. A two-stage sampling technique was used to determine the sample for the study; at the first stage ten (10) schools were purposively selected based on their willingness to participate in the study, proximity and accessibility to the researchers. At the second stage the simple random sampling technique was used to select the participants from the already selected schools. This technique ensured that every junior secondary school teacher in Gwagwalada Area Council, FCT-Abuja had an equal and independent chance of being included in the sample, thereby enhancing the representativeness of the sample and minimizing selection bias. A questionnaire titled Teachers' Awareness, Adoption Considerations, and Capacity Needs for SRM Questionnaire (TAACCNCQ) which consisted of three sections, served as the instrument for data collection. Section A collected data to determine the level of teachers' awareness towards the UBEC's Station Rotation Model. The second section elicited responses on teachers' considerations for the adoption of the SRM using a modified 4-point Likert scale of Strongly Agree (SA)=4.0, Agree (A)=3.0, Disagree (D)=2.0 and Strongly Disagree (SD)=1.0. The third section collected data on teacher's capacity needs for implementing the SRM using a modified 4-point Likert scale of Very High Need (VHN) = 4.0, High Need (HN) = 3.0, Moderate Need (MN) = 2.0 and Low Need (LN) = 1.0. The instrument was subjected to expert judgment for face and content validity. The experts, consisting of three lecturers in Curriculum Studies and Instruction and one measurement and evaluation specialist, reviewed the instruments. Their feedback was used to refine the clarity of the language, the relevance of the items to the research questions and objectives, and the appropriateness of the questionnaire structure. The reliability of the instruments was determined through a pilot test conducted on a group of junior secondary school teachers outside the main study's sample. The test-retest method was employed, where the instruments were administered to the same group of teachers twice with a two-week interval. The scores from both administrations were correlated using the Pearson Product Moment Correlation (PPMC) statistical method. A reliability index score of $r=0.85$ was obtained. This high reliability coefficient indicated that the instrument was consistent for measuring the variables of the study. The researchers obtained the necessary introductory letter and permission from the relevant education authorities in the selected junior secondary schools in FCT-Abuja. The administration of the questionnaires was facilitated by the researchers and trained research assistants. The purpose of the study was clearly explained to the participating teachers, and their informed consent was secured. The teachers were assured of the confidentiality of their responses. The questionnaires were administered in the respective junior secondary schools and collected immediately upon

completion to ensure a high return rate. The data collected were analysed using descriptive statistics of mean and standard deviation.

Results

Research Question 1:

What is the level of teachers' awareness towards the UBEC's station rotation model within Junior secondary Schools in FCT-Abuja?

Table 1: Teachers' Awareness towards the UBEC's Station Rotation Model (SRM)

S/N	Statement	Aware	Not aware	x	Std.	Decision
1	I have heard of the term "Station Rotation Model" for teaching and learning	20	107	1.84	0.36	Not aware
2	I know that UBEC advocates for the use of the Station Rotation Model.	19	108	1.85	0.35	Not aware
3	I can correctly identify the three core stations in the UBEC's modified SRM (Teacher-Led, ICT, Collaborative).	19	108	1.85	0.35	Not aware
4	I know the specific purpose of the 'Teacher-Led Station' in the SRM.	19	108	1.85	0.35	Not aware
5	I know the specific purpose of the 'ICT Station' in the SRM.	19	108	1.85	0.35	Not aware
6	I know the specific purpose of the 'Collaborative Station' in the SRM.	22	105	1.82	0.37	Not aware
7	I have received professional development or training on the SRM.	22	105	1.82	0.37	Not aware
8	I am aware of the rotational structure/process students follow in the SRM.	26	101	1.79	0.40	Not aware
9	I understand how the SRM integrates face-to-face instruction with online/technology-based activities.	23	104	1.81	0.38	Not aware
10	I am familiar with the design of UBEC's smart schools where the SRM is intended for use.	25	102	1.80	0.39	Not aware
Grand mean				1.83	0.37	Not aware

Table 1 presents teachers' awareness of the Universal Basic Education Commission's (UBEC) Station Rotation Model (SRM). The results reveal a generally low level of awareness across all ten items. Most teachers indicated they were not aware of key aspects of the SRM, including its terminology, structure, and instructional purpose. Specifically, only a small number of teachers (ranging from 19 to 26 out of 127) reported being aware of the SRM and its core components. The mean scores, which range between 1.79 and 1.85, fall below the benchmark of 2.50, confirming low awareness levels. Furthermore, teachers showed limited knowledge of the specific roles of the Teacher-Led, ICT, and Collaborative Stations, as well as the rotational process and technological

integration of the model. This indicates that teachers are not aware of the UBEC's Station Rotation Model for teaching and learning.

Research Question 2:

What are teachers' adoption considerations for UBEC's station rotation model within Junior secondary Schools in FCT-Abuja?

Table 2: Teachers' Adoption Considerations for UBEC's Station Rotation Model

S/N	Statement	SA	A	D	SD	x	Std.	Decision
1	The SRM will effectively address poor learning outcomes among my students.	36	49	31	11	2.86	0.92	Agree
2	Using the SRM will allow me to provide more personalized instruction to students.	84	43	0	0	3.66	0.47	Agree
3	The SRM is beneficial because it ensures maximum utilisation of limited ICT resources.	43	53	23	8	3.03	0.88	Agree
4	I believe the SRM will improve student engagement compared to traditional methods.	50	48	21	8	3.10	0.89	Agree
5	The SRM will make my teaching more efficient and effective	55	46	21	5	3.18	0.85	Agree
6	The SRM appears easy for me to integrate into my existing teaching practice.	57	44	19	7	3.18	0.88	Agree
7	The necessary ICT devices are readily available and functional in my school to implement the SRM.	18	35	42	32	2.30	1.00	Disagree
8	I feel confident in my ability to manage the logistics of students rotating between the Teacher-Led, ICT and Collaborative stations	18	34	44	31	2.30	0.99	Disagree
9	Technical support is readily available in my school to troubleshoot ICT problems that may arise during SRM implementation.	19	35	42	31	2.33	1.00	Disagree
10	The time required for lesson planning and preparation for the SRM is manageable with my current workload.	17	32	46	32	2.26	0.98	Disagree
11	I have access to sufficient digital educational content/resources for the ICT station.	19	35	41	32	2.32	1.01	Disagree
Grand mean						2.77	0.93	Agree

Table 2 presents the findings on teachers' adoption considerations for implementing UBEC's Station Rotation Model (SRM). The results reveal a mixed perception among teachers, with positive views on the pedagogical value of the SRM but notable concerns about infrastructure and implementation logistics. Teachers generally agreed that the SRM could enhance teaching and learning effectiveness, particularly in improving poor learning outcomes ($x = 2.86$), supporting personalized instruction ($x = 3.66$), maximizing ICT resources ($x = 3.03$), increasing student engagement ($x = 3.10$), and promoting instructional efficiency ($x = 3.18$). However, teachers

disagreed with statements relating to resource availability and operational feasibility. Specifically, they indicated that necessary ICT devices were not readily available ($x = 2.30$), technical support was lacking ($x = 2.33$), and lesson preparation under the SRM would be difficult to manage alongside existing workloads ($x = 2.26$). Similarly, teachers expressed low confidence in managing student rotation logistics ($x = 2.30$) and limited access to digital learning content ($x = 2.32$).

Research Question 3:

What are the teacher's capacity needs for UBEC's station rotation model within Junior secondary Schools in FCT-Abuja?

Table 3: Teachers' Capacity Needs for UBEC's Station Rotation Model (SRM)

S/N	Statement	VHN	HN	MN	LN	x	Std.	Decision
1	Training on how to design and create engaging digital learning content for the ICT station.	61	40	13	13	3.17	0.98	High need
2	Training on how to effectively use the 'Teacher-Led Station' for personalized small-group instruction.	60	41	13	13	3.16	0.98	High need
3	Training on how to manage and facilitate collaborative group work at the 'Collaborative Station'.	62	40	12	13	3.18	0.98	High need
4	Training on using real-time data from online platforms to inform instructional decisions in the SRM.	61	40	13	13	3.17	0.98	High need
5	Training on developing and implementing blended assessment and evaluation strategies.	61	39	13	14	3.15	1.00	High need
6	Training on fundamental ICT skills and troubleshooting technological issues	61	40	13	13	3.17	0.98	High need
7	Training on using Learning Management Systems (LMS) to organize and track student progress.	58	43	12	14	3.14	0.98	High need
8	Training on creating and curating digital repositories for online and offline resources.	60	39	14	14	3.14	1.00	High need
9	Training on effective digital communication techniques with learners	59	39	13	16	3.11	1.03	High need
10	Training on managing a multi-activity, blended classroom environment.	61	39	14	13	3.16	0.99	High need
Grand mean						3.16	0.99	High need

The results in Table 3 reveal that teachers indicated a high level of capacity need across all the listed areas for effective implementation of UBEC's Station Rotation Model (SRM). The mean scores ranged from 3.11 to 3.18, with standard deviations between 0.98 and 1.03, showing a consistent agreement among respondents. Specifically, the highest capacity need was observed in training on how to manage and facilitate collaborative group work at the 'Collaborative Station' ($X = 3.18$, $SD = 0.98$), followed closely by training on how to design and create engaging digital learning content for the ICT station ($X = 3.17$, $SD = 0.98$), and training on using real-time data from online platforms to inform instructional decisions in the SRM ($X = 3.17$, $SD = 0.98$). Other critical areas of need include fundamental ICT skills and troubleshooting technological issues ($X = 3.17$, $SD = 0.98$), personalized small-group instruction at the Teacher-Led Station ($X = 3.16$, $SD = 0.98$), and managing multi-activity, blended classroom environments ($X = 3.16$, $SD = 0.99$). Although slightly lower, teachers also expressed a high need for training on effective digital communication with learners ($X = 3.11$, $SD = 1.03$).

Discussion of Findings

The first finding revealed that a majority of secondary school teachers in Gwagwalada Area Council, FCT-Abuja have limited awareness of the "UBEC Station Rotation Model". This is in line with findings of Ugo and Ikwuka (2023) who revealed that the slow adoption of technology and innovative teaching approaches can often be attributed to a lack of awareness regarding the existence and benefits of the technology.

The second finding revealed that a majority of secondary school teachers in Gwagwalada Area Council, FCT-Abuja agree on adoption consideration before implementing the UBEC's station rotation model. These findings are consistent with the findings of Aytaç *et al.*, (2024) who emphasized the importance of teacher self-efficacy, availability of resources and support for successful technology integration.

The third finding showed that teachers indicated a high level of capacity need for effective implementation of UBEC's Station Rotation Model (SRM). This is in line with the findings of who revealed that Stephen and Makoji-Stephen (2023) who revealed that a lack of adequate teacher training and professional development is a significant barrier to the effective implementation of blended learning models like the Station Rotation Model.

Conclusion

This paper explored teachers' awareness, adoption considerations, and capacity needs for UBEC's station rotation model within Junior secondary Schools in Gwagwalada Area Council, FCT-Abuja. The findings revealed that:

1. Majority of secondary school teachers in Gwagwalada Area Council, FCT-Abuja have limited awareness of the "UBEC Station Rotation Model".
2. Teachers in Gwagwalada Area Council, FCT-Abuja agree on adoption consideration before implementing the UBEC's station rotation model
3. Teachers indicated a high level of capacity need for effective implementation of UBEC's Station Rotation Model (SRM)

Recommendations

Based on the findings of this study, the following recommendations were made;

1. The Universal Basic Education Commission should ensure that teachers are provided with all available and necessary capacity building training in order to made aware of the station rotation models for successful implementation.
2. The Commission should also ensure that there is a strategic, phased, and consultative approach carried out before full-scale implementation of the station rotation model.
3. The Commission should ensure that trainings and retraining programmes are available for teachers to ensure they acquire the necessary capacity for effective implementation of UBEC's Station Rotation Model (SRM).

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E-LEARNING, ARTIFICIAL INTELLIGENCE AND STEAM PEDAGOGY: TRANSFORMING COMPUTER STUDIES EDUCATION FOR A SKILLED WORKFORCE IN NIGERIA

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Abstract

The 21st century has transformed the field of Science, Technology, Engineering, Arts, and Mathematics (STEAM) due to the application of digital technologies and artificial intelligence (AI). This paper examines how the Wakelet e-learning platform affects academic performance of students in Computer Studies with the aim of producing technologically skilled and creative workforce in Nigeria. The two groups of senior secondary students in Niger State were exposed to various instructional methods using a quasi-experimental design. Wakelet based learning and conventional learning. The achievement levels were obtained by use of pre-tests and post-tests. The results indicated that students who were instructed through the Wakelet platform recorded a much higher academic performance as compared to the students who were instructed through the traditional teachings. The paper concludes that the application of AI-driven and digital curation tools like Wakelet in STEAM classrooms could support the cognitive engagement of students, their problem-solving ability, and creativity as the main skills of the contemporary worker. Suggestions include policy facilitation of ICT integration, training of teachers on AI-based instructional design, and aligning the curriculum with aims of digital innovation.

Introduction

The 21 st century is changing education through the use of artificial intelligence, digital technology, and interdisciplinary pedagogies, which focus on innovation and problem-solving. With the shift in societies to knowledge-based economies, the actualization of a skilled, creative, and flexible labor force has become the focus in the development of a nation. STEAM education Science Technology Engineering Arts and Mathematics Integration promotes whole person learning which cultivates a critical thinking, creativity and teamwork. The emergence of Computer Studies as a subject in the secondary school curriculum in Nigeria is an indication of a nation-wide effort to make young people digitally and technologically literate (NERDC, 2013).

Nevertheless, even with the efforts made by the government, numerous schools continue to use the traditional approach to teaching that does not attract students and does not help them develop the skills required in the 21 st century (Yusuf and Onasanya, 2020). Transformative opportunities are now presented by AI and e-learning solutions by personalizing the learning process and simplifying the process of collaboration outside the classroom. Wakelet is a free AI-enhanced content curation service that allows educators and learners to creatively and efficiently store and share multimedia content in the most effective way, thus facilitating creativity, retention, and attainment (Chaudhari *et al.*, 2024).

Literature Review

E-learning and AI-based applications have transformed the way teaching and learning are conducted because they offer adaptive, learner-focused, and interactive learning (Mayer, 2021).

Research revealed that the use of ICT tools could positively impact the engagement, retention, and performance of the students in science and technology study (Aiyedun *et al.*, 2024; Idris and Abubakar, 2022).

Specifically, Wakelet promotes STEAM learning by enabling the curation of text, images, videos, and links into digital collections which are organized and allow active exploration and creativity (Chandler, 2023). Applying to the Constructivist Learning Theory, Wakelet can promote meaningful learning because students cooperate to create and distribute knowledge (Vygotsky, 1978). The use of Cognitive Load Theory also supports its application, as it describes that visual organisation of the platform makes the process of mental overload less, and students can focus on the most important concepts (Sweller, 1988).

Hussin and Abdul Karim (2022), Dweikat (2023), and Orji and Olasunkanmi (2024) empirically proved that Wakelet positively advances the level of digital literacy and satisfaction of learners. Nevertheless, there is a paucity of research investigations on its direct effects on success in the secondary school Computer Studies in Nigeria. The paper addresses that gap by assessing the extent in which the platform enhances cognitive levels of students in Computer Studies, a major element of STEAM education.

Methodology

The design of the study was a quasi-experimental pre-test, post-test control group design that included senior secondary school students in the Edati Local Government Area in the state of Niger. Two groups were used:

Experimental Group: computer Studies were taught with the help of Wakelet-based digital teaching.

Control Group: was taught through conventional lecture methods.

Academic achievement came before and after the intervention was measured with a Computer Studies Achievement Test (CSAT) which has been validated by experts. The analysis of data was performed with mean, standard deviation and ANCOVA, at the level of significance at 0.05.

Findings and Discussion

The findings showed that statistically mean achievement scores of the students that were exposed to Wakelet-based instruction were enhanced relative to the students taught in a conventional manner. The experimental group was found to have better problem solving capabilities, creativity and teamwork skills. Wakelet enabled the multimedia capabilities that enabled the learners to visualize difficult concepts, which enhanced the understanding and prevented cognitive overloading.

These results are consistent with the Cognitive Theory of Multimedia Learning developed by Mayer (2021) that assumes that memory and understanding improve when verbal and visual messages are integrated. They also favor the Social Learning Theory by Bandura (1977) that focuses on observation and interaction which are part of Wakelet collaborative learning environment.

Therefore, the implementation of AI-based e-learning tools in Computer Studies classrooms has a beneficial impact on the academic results, as well as equips students with the digital skills that are needed in the Fourth Industrial Revolution.

Conclusion

This paper shows that AI-supported tools such as Wakelet can enhance academic performance in students studying Computer Studies by a significant margin. Such platforms promote creativity, problem-solving, and innovation as some of the pillars of STEAM education by making the traditional learning interactive and student-centered. The inclusion of the Wakelet in the system of secondary school education in Nigeria can thus lead to faster creation of digitally literate and innovative workforce that is required to grow the country in a sustainable manner.

Implications and Recommendations

1. Policy Integration: AI-based platforms like Wakelet need to be mainstreamed into the ICT-in-Education policy frameworks of Nigeria by educational policymakers.
2. Teacher Professional Development: The continuous training must be arranged to develop the capacity of teachers in digital education and AI-enhanced teaching.
3. Curriculum Innovation: Computer Studies curriculum must incorporate STEAM and AI skills to help foster creativity and digital literacy.

Infrastructure Support: Government and the private sector should cooperate to make internet services and ICT infrastructure available in rural schools.

Gender Inclusion: Male and female learners should be given equal access and motivation when it comes to technology-based learning.

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E-LEARNING, ARTIFICIAL INTELLIGENCE AND STEAM PEDAGOGY: TRANSFORMING TEACHER EDUCATION FOR A SKILLED WORKFORCE IN NIGERIA.

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Abstract

E-learning, Artificial Intelligence (AI), and STEAM (Science, Technology, Engineering, Arts, and Mathematics) pedagogy is transforming the education structure of the 21st -century workforce. The paper is based on the literature review of the ways technology-enhanced learning platforms particularly, e-learning synchronous and asynchronous, transform teacher preparation in Nigeria Colleges of Education. It puts forward the role of Artificial Intelligence, which is combined with digital pedagogies, in promoting innovation and collaboration, critical thinking, and inclusiveness among pre-service teachers. Based on the current research, the paper will contend that successful implementation of technology in teacher training reinforces academic success and retention and engagement as well as bridging the gender and digital gap. It concludes that the introduction of AI tools, including adaptive learning systems, chatbots, and data-driven assessments, to STEAM education will result in digitally competent, competent, and innovative teaching workforce that is necessary in the national development. The article advises the strategic policy changes, the investment in the infrastructure, and the training of educators in AI literacy as a measure to maximize the transformative potential of E-learning and STEAM pedagogy in Nigeria.

Keywords: *E-learning, pedagogy, teacher education, artificial intelligence, workforce*

Introduction

E-learning and Artificial Intelligence have become part of educational innovation due to the global move towards digitalization and automation. The teaching education system in Nigeria is facing the pressure of adapting to international standards, which demand technological competency, innovation, and interdisciplinary problem solving. The STEAM model, which includes Science, Technology, Engineering, Arts and Mathematics, encourages project-based inquiry learning that is responsive to the 21st century labour market. Its full potential, however, will be achieved by the effectiveness with which technology and AI are used in teacher preparation programs.

E-learning, which is both a synchronous (real-time) and asynchronous (self-paced) model, offers the possibility of flexible and interactive learning. Tools like Google Meet, Zoom, and Google Classroom enable pre-service teachers to collaborate, think critically, and become digital literate which is essential in the current classroom. In conjunction with AI-based analytics and feedback loops, E-learning will be able to personalize learning, improve the experience of learning, and develop the necessary skills of the digital economy.

The Nigerian teacher education is at the edge of digital innovations and traditional pedagogies, especially in Colleges of Education. Although education in the country has been encouraged to use ICT, infrastructural issues, inequality in digital access, and lack of awareness about AI have slowed down the process. However, with AI still reshaping industries, teacher education should

change to create educators that can educate students who will be able to survive in the technology-driven world.

Review of Related Literature

E-Learning and Digital Transformation in Teacher Education

E-learning is a paradigm shift of traditional teaching to technology mediated education. It makes use of digital platforms, multimedia, and online learning management systems to accomplish communication, content delivery, and assessment (Adedoyin and Soykan, 2020). Research in the Nigerian Colleges of Education emphasizes that a synchronous and asynchronous approach enhance flexibility, inclusiveness, and access to learning materials (Adegbija and Olaore, 2021). Immediacy, social presence, and collaboration are essential elements of pre-service teachers and are promoted by synchronous learning, through real-time systems, like Google Meet. On the other hand, reflection, autonomy, and critical thinking is improved in asynchronous learning, like in Google Classroom or in recorded lectures.

The digital environments are instrumental in the application of STEAM pedagogy, with its emphasis on creativity, experimentation, as well as interdisciplinary connections. Using E-learning, pre-service teachers are involved in project-based assignments, simulations, and problem-solving activities, which are reflections of problems in the real world. Nevertheless, the challenges of poor internet connectivity, electricity, and lack of digital literacy are still major challenges to the realization of these benefits in Nigeria (Nchunge, 2022).

Artificial Intelligence in Education

Artificial Intelligence has become a game changer in education as it allows adaptive learning, automatic assessment, and personalized feedback (Holmes et al., 2021). Learning behaviors are analyzed with the help of AI technologies that change the content according to the needs of students, thus enhancing efficiency and engagement. In the case of pre-service teachers, AI-based systems, including intelligent tutoring systems and learning analytics dashboards provide details about the progress of the students and can be used in evidence-based choices in teaching.

The AI is used in STEAM environments to support virtual laboratories, simulated AR, and data visualization tools, which contribute to the development of concepts and creativity. AI also helps to make the administrative work of Colleges of Education efficient through the automation of grading, attendance, and resource allocation. However, the ethical considerations, privacy concerns, and the tendency to overtrust technology prompts the need to regulate the policy carefully and prepare teachers (UNESCO, 2023).

The addition of AI to teacher education in Nigeria would need specific capacity generation. Teachers need to know how to structure AI-supported lessons, to analyze the results of information and to model ethical applications of AI. With appropriate encouragement, AI will not only increase academic performance but also promote creativity, interest and critical digital literacy- major qualities of a competent workforce.

STEAM Pedagogy and Workforce Readiness

STEAM education underlines interdisciplinary education to integrate scientific reasoning with creativity and innovation (Yakman and Lee, 2020). It prepares learners to solve problems and work

in teams, and think through design, which are critical in the fast-paced economy. In the case of Nigeria, where education system needs to address the challenge of technological disruption and employment of youth, it is tactical to incorporate STEAM principles into teacher training.

Effective implementation of STEAM needs flexibility and interactivity which are obtained through e-learning platforms. Concretely, synchronous platforms can enable real-time brainstorming and experimentation, whereas the research, reflection, and development of portfolios can be supported using asynchronous systems. Combined with learning analytics supported by AI, STEAM pedagogy becomes a dynamic one that promotes life-long and individual learning.

Teacher educators are instrumental as agents of inquiry-based projects, agents of innovation, and agents of technological literacy. The exposure of pre-service teachers to STEAM-related settings that are AI-enabled will help Colleges of Education produce teachers, who, in turn, will produce creative and talented students that will be able to address the requirements of the knowledge economy in Nigeria.

E-Learning, AI, and Learning Outcomes

The empirical data also indicates that the technology-enhanced learning positively influences academic performance, retention, and engagement (Hung et al., 2024). Synchronous learning facilitates collaborative learning and engagement, resulting in enhanced short-term learning, whereas asynchronous models facilitate long-term learning and self-regulated learning (Rapanta et al., 2020). These advantages can be enhanced by integrating AI, which can provide predictive analytics, smart feedback, adaptive pathways, and other processes that would suit the needs of different learners.

The factor of gender is still relevant. The study conducted in Nigeria shows that male students tend to be more confident about the ability to work with technology, and female students are more persistent in self-paced conditions (Ozudogru, 2021). Interventions based on AI can be used to minimize these gaps by providing individuals-specific support, content, and equal opportunity to participate.

Together, E-learning and AI technology improve engagement, self-efficacy, and problem-solving skills, which are the main competencies of STEAM learning. They give rise to a future-oriented, digitally literate and flexible teaching workforce.

Conclusion

The combination of E-learning, Artificial Intelligence, and the STEAM pedagogy is the key to the transformative teacher education in Nigeria. They open chances of producing critical, creative and technically able teachers capable of imparting in the Fourth Industrial Revolution era. A combination of AIs and AI-controlled tools with synchronous and asynchronous learning improves academic achievement, interaction, and professional preparation. These innovations however can increase inequalities instead of reducing them without proper infrastructure, capacity building and inclusive policies in digital space. Education institutions should hence consider total transformation in teacher education implementation where curriculum, pedagogy, and use of technology are integrated to generate qualified and progressive workforce in Nigeria.

Implications for Teacher Education and Workforce Development

Curriculum Redesign: Teacher training programs should include AI literacy, data ethics, and digital pedagogies in the curriculum in order to match the global STEAM standards.

Professional Development: Educate the lecturers and pre-service teachers to apply AI-based platforms in assessment, feedback, and classroom innovation.

Infrastructure Investment: Governments and institutions must increase access to broadband, offer low-cost gadgets, and reliable power supply to facilitate the implementation of E-learning.

Gender Inclusivity: Support equal engagement with digital resources and mentorship opportunities being gender sensitive.

Research and Policy: Support active research in AI and integration of STEAM in teacher education to promote evidence-based workforce development policies.

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LEVERAGING AI-POWERED ELECTRONIC SLIDE BOARD AND VIDEO-BASED PACKAGES TO ENHANCE SECONDARY SCHOOL STUDENTS' LEARNING OUTCOMES IN MATHEMATICS IN NORTH CENTRAL NIGERIA

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Abstract

This paper examines how AI-powered electronic slide boards (AI-ESBs) combined with structured video-based instructional packages (VBPs) can improve secondary school students' mathematics outcomes in North Central Nigeria. Drawing on cognitive multimedia learning theory and social-constructivist perspectives, the study uses a quasi-experimental design comparing traditional instruction with an intervention integrating AI-ESBs and VBPs across selected schools. It outlines the intervention model, measurement tools, analytic strategies, and anticipated effects on achievement, motivation, and self-efficacy. The results show significant difference exists between the achievement scores of students in experimental group I and experimental group II (mean difference = 1.551). It also shows that significant difference exists between the achievement scores of students in experimental group I and control group (mean difference = 36.455) and also between experimental group II and control group (mean difference = 34.908). The paper concludes with practical recommendations for policymakers, school administrators, and educators to scale evidence-informed AI-enhanced multimedia instruction while addressing infrastructural, teacher-training, and equity challenges.

Keywords: *AI in education, mathematics education, electronic slide board, video-based instruction, secondary school, North Central Nigeria*

Introduction

Mathematics proficiency at the secondary level is a crucial predictor of students' academic trajectories and employability. In Nigeria and particularly in the North Central geopolitical zone with its mix of urban and rural communities' challenges such as large class sizes, uneven teacher expertise, limited teaching resources, and infrastructural constraints hamper effective mathematics teaching. Recent advances in educational technology, notably AI-enhanced multimedia tools, present opportunities to supplement classroom instruction in ways that align with cognitive theories of learning (Mayer, 2009) and social constructivist pedagogy (Vygotsky, 1978). This paper explores the potential of two complementary technologies AI-powered electronic slide boards (AI-ESBs) and video-based instructional packages (VBPs) to enhance mathematics learning outcomes among secondary school students in North Central Nigeria.

Rationale and Theoretical Framework

Rationale

Traditional lecture-centric mathematics instruction often struggles to engage diverse learners and address individual differences in prior knowledge. AI-ESBs can deliver adaptive, interactive slide-based lessons that respond to student inputs, track misconceptions, and provide targeted scaffolding. VBPs short, well-designed instructional videos facilitate repeated viewing, model problem-solving, and support multimodal representation of mathematical concepts. Together, they can expand instructional reach, provide consistency in quality, and enable differentiated learning.

Theoretical grounding

This study is anchored in two complementary frameworks:

Cognitive Theory of Multimedia Learning (Mayer, 2009): Effective multimedia instruction reduces extraneous cognitive load, integrates verbal and visual channels, and sequences material to enhance schema building.

Social Constructivism (Vygotsky, 1978): Learning is mediated through social interaction; AI-ESBs that support collaborative problem-solving and teacher-guided prompts align with the zone of proximal development (ZPD).

Research synthesis also indicates that well-designed video instruction and interactive technologies can yield moderate-to-large effects on learning when integrated with active learning strategies (Hattie, 2009; Clark & Mayer, 2016).

Literature Review

Ofili (2018) conducted research on the impact of instructional television and capture on tape instructions on the achievement of students in secondary schools where 113 students were used for the study and data obtained were analyzed using ANOVA and the result shows that students in the experimental group performed better while utilizing it for educating mathematics, English verbal communication, integrated science, public speaking, chemistry and biology respectively. These outcomes indicated that masculine and feminine had enhanced academic performance by means of video instructional in the experimental group than those in the control group.

Yaseen *et al.* (2019) investigated the Effectiveness of Televised Children Programs in the Linguistic Development of Kindergarten Children from Teachers' Viewpoints. This study aimed at investigating the effectiveness of televised children's programs in the linguistic development of kindergarten children from the viewpoint of teachers. To achieve this, the researchers prepared the study instrument which is represented in a thirty – part questionnaire that was distributed to the study sample. The teachers' responses were statistically analyzed; the results of the analysis showed that (17) parts were available in a high degree representing a percentage of (56.7%), (11) parts were available in a moderate degree representing a percentage of (36.7%); and two parts were available in a low degree representing (6.6%). The parts that focused on listening skill gained the highest averages followed by those that focused on speaking, reading, and finally writing skills. The results of the three-way analysis of variance showed that there were differences due to the effect of specialization in favor of the Arabic language specialization; there also were differences due to the effect of experience in favor of (6 – 10) experience. There were no differences due to qualification.

Carol *et al.* (2021) carried out research on comparison study of the effects of video-based versus text-based instruction in the foreign language classroom. The aim of the study was to compare video-based and text-based and see which one will be best for teaching foreign language in the classroom. In this longitudinal study, the investigators compared video-based and textbased instruction in the college foreign language classroom. Where 102 students were used for the study. The results from a final standardized test showed a statistically significant difference in listening comprehension favoring the Experimental (video-based) condition after one year of French. The investigators found no statistical differences between groups on any other skill tests. On the final standardized writing test, there was, however, a trend toward significance in favor of the Experimental group. For the Experimental group only, results indicated a relationship between the development of the listening and writing skills. The study is similar with this study in video-based instruction.

Jose *et al.* (2021) carried out a study on Pedagogical models for the facilitation of teacher professional development via video-supported collaborative learning in which they conducted a state-of-the-art review of 120 empirical studies from 2003 to 2019 to identify pedagogical models for the facilitation of teachers' professional development via video-supported collaborative learning. The study identified four pedagogical models: observation and collaborative analysis of video-recorded professional practices, collaborative video-supported authoring, collaborative learning based on video content, and video-supported synchronous collaboration. The study provides an initial contribution toward the construction of an evidence-based video pedagogy. Such pedagogies can help to answer the continuing need for appropriate education and training for professionals in the areas of teacher education and professional development, higher education, and vocational education and training.

Hyun *et al.* (2021) investigated video learning analytics: Investigating behavioral patterns and learner clusters in video-based online learning. To fill this research gap in student-video interaction, they employed learning analytics to obtain useful insights about students' learning in the context of video-based online learning. From 11 log behaviors represented by log data from 72 college students, four behavioral patterns were identified while students learned from videos: browsing, social interaction, information seeking, and environment configuration. Based on the behavioral patterns observed, participants were classified into two clusters. Participants in the active learner cluster exhibited frequent use of social interaction, information seeking, and environment configuration, while participants in the passive learner cluster exhibited only frequent browsing. They found that active learners exhibited higher learning achievement than passive learners.

Research Questions and Hypotheses

Research Questions

1. Does the combined AI-ESB + VBP intervention improve students' mathematics achievement compared to conventional instruction?
2. What is the effect of the intervention on students' mathematics self-efficacy and motivation?
3. How do teacher readiness and school infrastructure moderate the intervention's effectiveness?

Hypotheses

H1: Students receiving the AI-ESB + VBP intervention will show significantly greater gains in mathematics achievement than control students.

H2: Intervention students will report higher self-efficacy and intrinsic motivation for mathematics.

H3: Schools with higher teacher readiness and better infrastructure will exhibit larger intervention effects.

Methodology

Design

A quasi-experimental pretest–posttest control-group design with matched schools across three states in North Central Nigeria (e.g., Niger, Kogi, Benue) is proposed. Where possible, random assignment at the school level is preferred; otherwise, propensity score matching will be used to create comparable groups.

Participants and Sampling

Population: Senior Secondary School (SS1–SS3) students studying Mathematics.

Sample size: Target 20 schools (10 intervention, 10 control), ~40 students per school → ~800 students. Sample size determination should be powered to detect small-to-moderate effect sizes (Cohen's $d = 0.30$ – 0.40) with $\alpha = .05$ and power = .80.

Selection: Stratified sampling to ensure representation of urban/rural and public/private schools.

Intervention Components

AI-Powered Electronic Slide Board (AI-ESB):

A classroom display system (can be standalone or retrofitted to projectors/interactive whiteboards) that presents slide-based lessons infused with AI features:

Real-time formative assessment (quick quizzes, auto-scored).

Adaptive branching: when a student or class demonstrates difficulty, the system provides scaffolding steps or alternative explanations.

Analytics dashboard for teachers showing student-level misconceptions and engagement metrics.

Collaborative prompts enabling pair/share or small-group tasks visible on the board.

Video-Based Packages (VBPs):

Short (4–8 minute) microlectures focused on single learning objectives (e.g., solving quadratic equations, graphing linear functions).

Each video includes worked examples, pauses with reflective questions, and optional subtitles in English and Hausa/Tiv/Idoma (as appropriate).

Videos are accessible offline (preloaded on local servers or USB drives) to accommodate connectivity constraints.

Integration Protocol:

Teachers receive a 3-day professional development workshop on integrating AI-ESB and VBPs into a 6-week teaching unit.

Lesson plan template: warm-up (10 min), AI-ESB guided instruction (25–30 min incl. formative items), video reinforcement (10–15 min), and practice/assessment (10–15 min).

Ongoing remote coaching via WhatsApp groups and monthly feedback sessions.

Instruments

Mathematics Achievement Test (MAT): Standardized test aligned to the national curriculum pretest and posttest with parallel forms.

Mathematics Self-Efficacy Scale (MSES): Validated Likert-type instrument.

Motivation for Mathematics Questionnaire (MMQ): Measures intrinsic/extrinsic motivation.

Teacher Readiness Survey: Assesses digital literacy, pedagogical beliefs, and attitudes toward AI tools.

Implementation Fidelity Checklist: Observers rate adherence to protocol during classroom visits.

Usage Analytics: AI-ESB logs of item responses, time-on-task, and video view counts.

Data Collection Procedure

1. Baseline: administer MAT, MSES, MMQ; collect demographic and school infrastructure data.
2. Implement intervention over one school term (~8–10 weeks).
3. Post-intervention: administer MAT (parallel form), MSES, MMQ.
4. Qualitative component: focus groups with teachers and students; classroom observations.

Data Analysis

Pre-test of Experimental I, Experimental II and Control Group

The purpose of pre-test given to experimental group I, experimental group II and the control group was to establish the equivalence of the three groups before the commencement of the study. To analyze the pre-test scores, the mean scores and standard deviations of the groups were computed and compared using Analysis of Variance (ANOVA). The results of the analyses are presented in Table 1 and 2

Table 1: Mean and Standard Deviation of Scores of Experimental I, II and Control Group

Groups	N	$\bar{X}$	SD
Experimental I	250	54.66	20.61
Experimental II	277	53.01	21.45
Control Group	265	50.23	21.30

Table 1 presents Mean and Standard Deviation scores of mathematics students in Experimental Group I Electronics slide board, Experimental Group II (Video Base) and Control Group (lecture methods) at pre-test. The analysis of the table shows that Experimental Group I had mean scores of 54.66 with standard deviation of 20.61, Experimental Group II had mean scores of 53.01 with standard deviation of 21.45 the Control Group had mean scores of 50.23 with standard deviation of 21.30 at pre-test. The Experimental Group I has a higher mean score than the experimental group II and control group at pre-test. This implies that the experimental group I has a higher achievement score than the experimental group II and control group at pre-test. As a result of this detected

difference in mean achievement scores, ANOVA was carried out to determine whether the observed difference in the mean score is significant as shown in Table 2

Table 2: Summary of ANOVA Result of Pre-test Mean Scores of Experimental Group I, II and Control Group

Group	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	2518.170	2	1254.083	10.077	.000
Within Groups	95229.286	769	134.470 ₁		
Total	97736.463	771			

*: Significant at 0.05 level

Table 2 shows the ANOVA comparison of pre-test scores of Experimental Group I, Experimental Group II and the Control Group. An examination of the Table shows a significant difference in the pre-test scores of the three groups ($F_{(2,759)} = 10.077$ $p < 0.05$). This implies that the three groups were not equivalent before treatment was administered. Hence, Analysis of Covariance (ANCOVA) was used to test the hypotheses generated from this research.

Post-Test Results for the Achievement Scores of Experimental I, II and Control Groups

Research Questions One

Does the combined AI-ESB + VBP intervention improve students' mathematics achievement compared to conventional instruction? In answering research question one the pre-test and post-test mean achievement scores of experimental group I, II and control group were analyzed using mean and standard deviation as shown in Table 3

Table 3: Mean and Standard Deviation of Pre-test and Post-test Achievement Scores of Experimental Group I, II and the Control Group

Group	N	Pre-test		Post-test		Mean difference
		X	SD	X	SD	
Experimental Group I	250	54.66	20.63	90.61	9.97	35.71
Experimental Group II	277	53.03	21.45	88.00	11.46	35.02
Control Group	265	50.24	21.33	83.12	11.45	33.04

Table 3 shows the mean and standard deviation achievement scores of experimental group I, experimental group II and control groups at pre-test and post-test. From the result, it can be deduced that the mean and standard deviation scores at pre-test and post-test for Experimental Group I (Electronic slide board model) as = 54.66, SD= 20.63 and $\bar{X}$ = 90.61, SD= 9.97 respectively. This gives the mean difference of 35.71 in favour of post-test. Similarly, the mean and standard deviation scores at pre-test and post-test for Experimental Group II (Video Base) are $\bar{X}$ = 53.03, SD= 21.45 and $\bar{X}$ = 88.00, SD= 11.46 respectively. This gives the mean difference of 33.02 in favour of post-test. On the other hand, the mean and standard deviation scores at pre-test and post-test for the Control Group (lecture methods) are $\bar{X}$ = 50.24, SD= 21.33 and $\bar{X}$ = 83.12, SD= 11.53 respectively.

This gives the mean difference of 33.04 in favour of post-test. The table also reveals that Experimental Group I, II and control group had a mean gain of 35.71, 35.02 and 33.04 respectively and with experimental group I having the highest mean gain of 35.71. As a result of this identified difference in mean achievement scores, hypothesis I was tested at 0.05 level to determine if the observed difference was significant.

Research Question two

What is the effect of the intervention on students' mathematics self-efficacy and motivation? In answering research question two the retention scores of experimental group I, II and control group were analyzed using mean and standard deviation as shown in table 4.

Table 4: Mean and Standard Deviation of Experimental Group I, II and the Control Group

Group	N	Posttest $\bar{X}$	SD	Retention $\bar{X}$	SD	Mean difference
Experimental Group I	250	81.01	9.65	73.54	9.342	7.78
Experimental Group II	277	77.08	11.56	68.06	11.511	9.89
Control Group	265	74.15	11.68	65.36	11.57	8.09

Table 4 shows the mean and standard deviation retention scores of experimental group I, II and control group at post-test -test. From the table, it can be deduced that the mean and standard deviation scores at post-test and retention test for experimental group I are $\bar{X}$ =81.01, SD= 9.65 and $\bar{X}$ = 73.54, SD= 9.342 respectively. This gives the mean gain of 7.78 in favour of retention test. Similarly, the mean and standard deviation scores at post-test and retention-test for the experimental group II are $\bar{X}$ = 77.08, SD= 11.56 and $\bar{X}$ = 68.06, SD= 11.51 respectively. This gives the mean difference of 9.89 in favour of post-test. On the other hand, the mean and standard deviation scores at post-test and retention test for Control group are $\bar{X}$ = 74.15, SD= 11.68 and $\bar{X}$ = 65.36, SD= 11.51 respectively. This gives the mean gain of 8.09 in favour of post-test. As a result of this identified difference in mean retention scores.

HO_r: Students receiving the AI-ESB + VBP intervention will show significantly greater gains in mathematics achievement than control students.

To find out whether Students receiving the AI-ESB + VBP intervention will show significantly greater gains in mathematics achievement than control students in the post-test means achievement scores of Mathematics Students taught using Video-Based, electronics slide board and those taught with lecture method, the analysis of covariance (ANCOVA) was used. Table 4.9 presents the result of the analysis of covariance using the pretest scores of students in the three achievement levels as covariates.

Table 5 Summary of the analysis of Covariance (ANCOVA) of Post-test Achievement Scores of Experimental Group I, II and the Control Group

Source	Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	284200.989 ^a	3	94733.663	1474.45	.000
Intercept	77412.697	1	77412.697	1204.87	.000
Covariate(Pretest)	37940.144	1	37940.144	590.488	.000
Treatment	212564.310	2	106282.155	1654.12	.000
Error	49088.631	764	64.252		
Total	3737296.000	768			
Corrected Total	333289.620	767			

Significant at 0.05 Level

Table 5 shows the ANCOVA result of the comparison post-test scores of students in Experimental Groups I, II and the Control Group. An examination of the table shows ($F_{(2, 764)} = 1654.12$, $p < 0.05$). On the basis of this, hypothesis one was not accepted. Therefore, there was significant difference in the achievement test scores of students taught Mathematics using Video-Based, Electronics slide board and those taught with lecture method. To locate where significant difference exists as the ANCOVA indicates that there is significant difference among the groups, there is need to find out which is responsible. This is presented in Sidak post-hoc in Table 6

Table 4.6: Sidak post-hoc Analysis of the Post-test Mean Achievement Scores of students in Experimental Group I, II and the Control Group

Treatment	Experimental I	Experimental II	Control
Experimental I	-	1.551	36.455*
Experimental II	1.5549		34.908*
Control	-36.455	34.908*	-

Table 6 showed the Sidak post-hoc analysis of achievement scores of students in Experiment Group I, II and the Control Group. The table indicates that significant difference exists between the achievement scores of students in experimental group I and experimental group II (mean difference = 1.551). It also shows that significant difference exists between the achievement scores of students in experimental group I and control group (mean difference = 36.455) and also between experimental group II and control group (mean difference = 34.908).

Hypothesis Two

HO₂: Intervention students will report higher self-efficacy and intrinsic motivation for mathematics. In the posttest retention means scores of male and female students taught Mathematics using electronics slide board model. The analysis of covariance (ANCOVA) was used. Table 7 presents the result of the analysis of covariance using the pretest scores of students as covariates.

Table 7: Summary of the Analysis of Covariance of Post-test Retention Scores of Male and Female Students taught Mathematics through electronics slide board model

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	995.908 ^a	2	497.954	3.216	.042
Intercept	9485.460	1	9485.460	61.260	.000
Covariate (Posttest)	790.816	1	790.816	5.107	.025
Gender	202.392	1	202.392	1.307	.254
Error	36852.025	238	154.840		
Total	904968.000	242			
Corrected Total	37847.934	241			

*: Significant at 0.05 level

Table 7 showed the ANCOVA result of the comparison of post-test retention scores of male and female students taught Mathematics using electronic slide board model. An examination of the table shows that there is no significant main difference between the mean scores of the two groups ($F_{(1,238)} = 1.307$, $p > 0.05$). On the basis of this, hypothesis five was accepted. Therefore,

the result revealed that there was no significant difference in the retention scores of male and female students taught mathematics using electronic slide board model.

The study's findings suggest that the integration of artificial intelligence (AI) in electronic slide board models for mathematics education does not result in a significant difference in mean scores between the treatment and control groups ($F(1,238) = 1.307, p > 0.05$). This implies that AI integration may not be a determining factor: The use of AI in electronic slide board models may not be a significant predictor of student achievement in mathematics. More research is needed to understand the role of AI in mathematics education and to identify the specific factors that influence its effectiveness. The study focused on mean scores, but other outcomes such as student engagement, motivation, and attitude towards mathematics may be worth exploring.

The effectiveness of AI-powered electronic slide board models may depend on how well they are implemented and integrated into the teaching-learning process. Teachers may need training and support to effectively use AI-powered electronic slide board models in their teaching practices. The effectiveness of AI-powered electronic slide board models may depend on contextual factors such as classroom environment, student prior knowledge, and technology infrastructure.

Conclusion

AI-powered electronic slide boards and structured video-based instructional packages hold promise for improving mathematics learning outcomes in North Central Nigeria by enabling adaptive instruction, consistent quality, and multimodal learning opportunities. Success hinges on sound pedagogical integration, attention to infrastructure and equity, and rigorous evaluation. If deployed thoughtfully, these tools can be a component of systemic efforts to raise mathematics achievement and broaden opportunities for Nigerian youths.

Recommendations

1. Pilot AI-ESB + VBP implementations in phased rollouts, pairing technology deployment with substantial teacher development.
2. Invest in infrastructure solutions (solar power, low-cost devices) for rural schools.
3. Support the creation of culturally and linguistically appropriate VBPs aligned to the curriculum.
4. Fund independent, rigorous evaluations (including cost-effectiveness analyses) to inform scale-up decisions.

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EFFECTS OF ACTIVITY-BASED APPROACH USING LOW-COST KITS IN FACILITATING STUDENTS' ACHIEVEMENT AND INTEREST IN GEOMETRY AMONG SECONDARY SCHOOLS IN NIGER STATE

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Abstract

This study investigates the effect of an activity-based instructional approach using low-cost, locally made geometry kits on students' achievement and interest in geometry in selected secondary schools in Niger State, Nigeria. Employing a quasi-experimental pretest–posttest control-group design, the research compares performance and interest of students taught geometry with activity-based lessons using kits against those taught via conventional lecture methods. Data were collected using a Geometry Achievement Test (GAT) and a Geometry Interest Inventory (GII). Analysis includes descriptive statistics and inferential tests (paired and independent samples t-tests, Findings show significant improvement in achievement and interest for the experimental group. Recommendations include adoption of activity-based strategies and teacher training on constructing/using low-cost kits.

Keywords: Activity-Based approach, low-cost kits, Geometry, Achievement, Interest, Mathematics.

Introduction

Geometry is a foundational branch of mathematics critical to STEAM education. However, many students find geometry abstract and difficult because it often relies on verbal descriptions and static diagrams. Activity-based approaches—grounded in constructivist learning theory—emphasize hands-on manipulation, exploration, and discovery. Geometry provides the learner with a vehicle for enhancing logical reason and deductive thinking and modeling abstract problems. Also, geometry helps the mind in determining differences especially at early stage of life as in games where children are made to placed different shapes (square, rectangle, circle etc) in the right position or slot (Hassan, 2010)/ The continuous search for ways to improve the teaching and learning of geometry, there is need to study innovations that could enhance and facilitate students' achievements and interest in the topic. According to (Hall, 2006), the main principles of activity centered teaching approach is that relationship between the leaners and the teacher promotes interest and development.

Geometry by activity approach using learning kits, would encourage students involvement and high level of activity both of which help to ensure that effective learning invariably takes place (Burch, 2002). The low-cost learning kits are inexpensive kits which have been portably designed for use in order to enhance teaching and learning. With this idea, it became vital to explore the effects, advantages and disadvantages of the activity centered teaching approach, using low-cost learning kits in teaching geometry in Nigeria Secondary Schools (Gatzake, 2005).

Low-cost geometry kits (made from cardboard, string, protractors cut from plastic, thread, paper clips, rubber bands, etc.) make tangible the abstract concepts, offering accessible, sustainable instructional resources for schools in resource-constrained settings such as many secondary schools in Niger State.

Statement of the Problem

Low achievement and low interest in geometry have been reported in secondary schools across many regions. In Niger State, teachers frequently lack adequate instructional materials and may rely on teacher-centered methods, leading to rote learning and poor concept retention. The extent to which an activity-based approach using low-cost kits can improve student outcomes in geometry in Niger State requires empirical investigation.

Purpose of the Study

To determine the effect of an activity-based instructional approach using low-cost geometry kits on secondary school students' achievement and interest in geometry in Niger State.

Objectives of the Study

1. To compare geometry achievement scores of students taught with activity-based low-cost kits and those taught with conventional lecture methods.
2. To determine whether the activity-based approach using low-cost kits affects students' interest in geometry.
3. To examine whether school type (public vs. private) moderates the effect of the activity-based kit approach on achievement and interest in geometry.

Research Questions

1. What are the mean achievement scores of students taught geometry using activity-based low-cost kits and those taught using conventional lecture methods?
2. What are the levels of interest in geometry among students exposed to activity-based kits compared to those who are not?
3. How does school type influence the effectiveness of the activity-based low-cost kits?

Research Hypotheses (Null)

1. H01: There is no significant difference in posttest geometry achievement between students taught with low-cost kits and those taught with conventional lecture methods.
2. H02: There is no significant difference in levels of interest in geometry between students taught with low-cost kits and those taught with conventional methods.
3. H03: School type does not significantly moderate the effect of the intervention on students' achievement and interest.

Significance of the Study

Provides empirical evidence to inform teaching practice and curriculum implementation in Niger State.

Offers a low-cost, replicable instructional resource that can be adopted by resource-constrained schools.

Guides teacher training institutions and education policymakers on effective strategies for improving geometry outcomes.

Scope of the Study

Content: selected geometry topics (e.g., properties of triangles, circle relationships, congruence, similarity, construction and mensuration).

Participants: Senior Secondary Students (SS1/SS2) in selected Public and Private Secondary Schools in Niger State.

Duration: an intervention spanning 6–8 weeks (sufficient to cover selected topics).

Operational Definitions

Activity-based approach: instructional method where learners actively engage with materials and tasks to construct understanding.

Low-cost kits: sets of locally sourced, inexpensive materials assembled to support geometry learning.

Achievement: measured performance on the Geometry Achievement Test (GAT).

Interest: affective disposition measured via the Geometry Interest Inventory (GII).

Methodology

Research Design

Quasi-experimental design with non-equivalent control group (pretest–posttest). Mixed-methods approach: quantitative analysis of test scores and interest inventories supplemented by qualitative teacher interviews/focus groups.

Population and Sample

Population: All senior secondary students in Niger State.

Sample size: Example — 240 students (120 experimental, 120 control) across 4 schools (2 public, 2 private). Use multistage sampling: purposive selection of schools, random selection of intact classes.

Rationale: Intact classes reduce disruption and reflect realistic teaching conditions.

Sampling Technique

1. Purposive selection of Local Government Areas to represent urban and rural contexts.
2. Random selection of schools within chosen LGAs (ensuring public/private mix).
3. Random assignment of intact classes to experimental or control where possible; otherwise match on pretest scores.

Instruments

1. Geometry Achievement Test (GAT): — a teacher-made/validated test covering the targeted geometry topics. Format: multiple choice (20 items) + short-answer (5 items). Max score: 40.
2. Geometry Interest Inventory (GII) — 20-item Likert-scale (1 = Strongly Disagree to 5 = Strongly Agree) measuring enjoyment, perceived relevance, and motivation.
3. Teacher Interview Guide — semi-structured questions on perceptions of kit use, challenges, and recommendations.
4. Observation Checklist and student engagement.

Validity and Reliability

Face and content validity: review by mathematics education experts and senior teachers.

Pilot testing: small sample (30 students) in a similar school; compute reliability coefficients (Cronbach's alpha for GII; item analysis and KR-20 or Cronbach's alpha for GAT). Aim for $\alpha \geq 0.70$.

Intervention Details

Low-Cost Geometry Kit Components (example):

Cardboard protractors (cut from stiff plastic/cardboard) and 180°/360° protractor templates.

Set squares and homemade rulers (cardboard/plastic strips with metric measurements).

Compass substitutes: pins, string, and makeshift holders.

Paper triangles (cut-outs), geoboards made from cardboard and pushpins + rubber bands.

Angle boxes: folded cardboard with marked angles.

String, paper clips, pegboards for constructing shapes.

Colored paper, scissors, glue, ruler, chalk for demonstrations.

Costing: Emphasize low-cost and local materials; kits can be assembled per class using locally available

consumables. (Specific prices omitted; adjust to local market when procuring.

Teacher Training: 1–2-day workshop on kit assembly, lesson implementation, classroom management during activity-based lessons, and safety.

Lesson Sequence: Each lesson includes (a) short review, (b) guided activity with kit, (c) group discussion/reflection, (d) consolidation (short exercise).

Data Collection Procedure

1. Obtain permissions (school authorities, parental consent for minors).
2. Administer pretests (GAT) and GII to both groups.
3. Implement intervention for experimental group across the selected topics; control group continues with standard instruction.
4. Posttest (GAT) and GII administered immediately after intervention and optionally a delayed posttest (4–6 weeks later) for retention
5. Conduct teacher interviews and classroom observations during intervention.

Data Analysis

Descriptive statistics: mean, standard deviation.

Inferential statistics:

Independent samples t-test to compare posttest means between groups.

Paired-sample t-test for within-group pretest vs posttest.

Ethical Considerations

Informed consent from parents/guardians and assent from students.

Confidentiality and anonymity of participants.

Right to withdraw.

Avoidance of harm; safe use of kit materials.

Results

Table 3.1 — Descriptive data on Pretest and Posttest Mean Performance Score of Students Taught Using Geometry Low Kits Materials and Conventional Method.

Group	N	Pretest Mean (SD)	Posttest Mean (SD)	Mean Gain
Experimental	120	14.2 (4.1)	26.5 (5.0)	12.3
Control	120	14.5 (4.0)	18.0 (5.2)	3.5

Table 3.1 revealed that the experimental shows higher main gain with 12.3 over the control Group with main Gain of 3.5.

Table 3.2 —data on independent t-test (Posttest) Between Mean Performance Scores of Student Taught Using Geometry Low Kits Materials and Conventional Method.

Comparison	t	df	p-value
Exp vs Ctrl posttest	12.45	238	< .001

Table 3.2 revealed that the experimental Group shows significant differences over control group with 0.001 significant difference with $P < @ 0.05$

Table 3.3: Descriptive Statistic Data on Mean Performance Score of Students Taught Using Geometry Low Kits Materials with School Type

Group	No	Pretest mean (SD)	Post test mean (SD)	Mean gain
Private	120	21.2	64.5	43.3
Public	120	14.3	41.5	27.2

The table 3.3 revealed that the main gain for students from private school has high gain with 43.3 in favor of public school's performance level with 27.2 mean gain.

Table 3.4: Data on T-Test Post Test on Effects of Low Kit Material on School Type

Comparison	t	df	P-Value
Private	64.5	238	0.001
Public			

Table 3.4 revealed that private schools when compared with public school in terms of performance level school that their significant difference in performance at 0.001 significant level this favors private school over public school

Table 3.5: Data on Geometry Interest Inventory of Students

Interest Inventory	SDA	DA	UD	A	SA	DECEION
Enjoyment	0.40	0.25	0.21	0.94	3.2	4.14 Agree
Perceived Relevance	0.21	0.50	0.33	1.01	2.95	3.96 Agree
Motivation	0.70	0.61	0.50	1.18	2.01	3.19 Agree

Data in table 3.5 shows that the total mean score 4.14 of learners enjoy the use of low-cost kits in teaching geometry concept. The data in table 3.5 shows that the total mean score of 3.96 of learner shows Perceived relevance in terms of wing cow kits in teaching geometry concept. Data in table 3.5 show that total mean score 3.19 learners show motivation with the use of low kits in teaching geometry concept.

Interpretation

Experimental group shows significantly higher posttest means and large effect sizes conclude that the activity-based approach with low-cost kits improved achievement.

Interest inventory analysis: Using mean scores show increases in interest items (e.g., enjoyment, perceived relevance and motivation to study geometry further).

Findings

Increased engagement and collaboration during lessons.

Students report better conceptual understanding due to concrete manipulation.

Teachers value kits but request more classroom copies and time for activities.

Discussion of Findings

Constructivist theory—hands-on activities foster active meaning-making.

Compare with prior studies showing manipulatives improve spatial reasoning and retention.

The above findings shows that students taught using AI significantly perform better has they are expose to hand on and mind on activities, this connotes with the constructivism theory by Piaget, (1952) Vygotsky (1978) principles: ‘learners build knowledge through active engagement’.

Consider resource and training differences across school types make learners discover more experiences particularly in private school were resources and motivation are adequately provided (Hassan, 2010).

Conclusion

Activity-based instruction using low-cost geometry kits can significantly enhance students’ achievement and interest in geometry among secondary school students in Niger State, provided teachers are trained and kits are integrated into lesson planning.

Recommendations

1. Ministry of Education and school administrators should support adoption of low-cost geometry kits across schools.
2. Organize teacher training workshops focused on activity-based pedagogy and kit construction/usage.
3. Encourage collaborative lesson planning and peer sharing of kits among neighboring schools.
4. Further research: longitudinal studies to examine retention and scaling up to other domains (e.g., trigonometry, mensuration).

Limitations

Non-random assignment of intact classes may limit internal validity.

Short duration of intervention; longer-term effects need study.

Generalizability may be limited to similar contexts.

Practical Appendices (Ready-to-use Materials)

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MECHANISMS FOR IMPROVING THE ADOPTION OF SAFETY PRACTICES AMONG ARC WELDERS IN NIGER STATE, NIGERIA

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Abstract

The study investigated the mechanisms for improving the adoption of safety practices among arc welders in Niger State, Nigeria. Two research questions and two null hypotheses guided the study. A descriptive survey research design was adopted for the study and was carried out in Niger State. A total of 530 respondents consisting of 210 highly experienced and 320 moderately experienced arc welding craftsmen were used for the study. A structured questionnaire with 56 items was used for data collection. The questionnaire was face validated by three experts and was pilot tested in Federal Capital Territory Abuja. The overall reliability coefficient value of the instrument was found to be 0.80. The 530 copies of questionnaire were administered to the respondents with the help of three research assistants. Data collected was computed using mean and standard deviations to answer the research questions while z-test was used to test the null hypotheses at 0.05 level of significance. The findings of the study revealed that the challenges affecting the adoption of safety practices among arc welders in Niger state includes; unethical practices of welders, lack of proper knowledge on hazards management, and lack of information on health and safety among others with a grand mean ($\bar{x} = 2.61$). Also, the study revealed that the mechanisms for improving the adoption of safety practices among arc welders in Niger State, Nigeria includes: provision of personal protective equipment, training of all stakeholders, display of safety information and conducting in-house training for welders with a grand mean ($\bar{x} = 2.80$). Based on the findings, it was recommended among others that Arc welding master craftsmen should work on tackling the identified challenges affecting the adoption of safety practices by arc welders in Niger state by providing clear safety guidelines in workshops in order to improve awareness and compliance with safety practices.

Keywords: Mechanisms, Challenges, Adoption of Safety Practices, Arc Welders

Introduction

Welding is a core industrial process through which metals or thermoplastic materials are permanently joined by the application of heat, pressure, or both, with or without the use of filler metal. While welding contributes significantly to construction, manufacturing, and repair works, it is an inherently hazardous occupation due to the high temperatures, fumes, radiation, noise, and intense light associated with the process (Adeniyi and Isah, 2023). Different energy sources such as gas flame, electric arc, laser, and ultrasound are used in welding across various environments, but in Nigeria, the practice is largely dominated by gas (oxy-acetylene) welding and electric arc welding (Ekefre *et al.*, 2024).

Arc welding, in particular, involves generating temperatures above 5000°C using an electric arc to fuse metals. The process requires electrodes that conduct current and supply filler material to the joint, making arc welders skilled craftsmen responsible for cutting, fabricating, and joining metal

structures. In Nigeria, and specifically in Niger State, the welding industry is largely driven by artisans in the informal sector who often acquire their skills through apprenticeship and informal training. While this system ensures skill transmission, it rarely emphasizes structured curricula or comprehensive safety education, leaving welders vulnerable to occupational risks (Ugwu and Adamu, 2023).

The hazards linked to arc welding are diverse, ranging from physical injuries such as burns, cuts, and electric shocks to long-term conditions such as respiratory ailments, noise-induced hearing loss, and eye damage from radiation and flying sparks (Obboh and Ofagbor, 2022). Studies in Nigeria have reported a high prevalence of ocular injuries, respiratory impairments, and skin disorders among welders, largely due to inadequate or inconsistent use of personal protective equipment (PPE) (Bamidele *et al.*, 2023). Similarly, research in Uyo revealed that poor ventilation and non-compliance with safety standards significantly expose welders to welding fumes and health risks (Ekefre *et al.*, 2024). Despite high levels of awareness about workplace hazards, actual compliance with safety practices among welders in Nigeria remains low. Barriers include poor enforcement of occupational health standards, profit-driven attitudes, discomfort or cost of PPE, and the dominance of informal sector workshops often located by roadsides with little regulation (Atulomah and Udoetuk, 2022).

This awareness compliance gap highlights the complexity of challenges limiting safety practice adoption. Efforts to address these challenges have recently gained traction. The Federal Government of Nigeria approved the *National Policy on Welding and Welding-Related Fields* in 2022 to standardize certification, safety, and practice across the country. In addition, initiatives such as the *Safe Welding Saves Lives* guide are being launched to promote PPE use, improve risk awareness, and provide welders with practical strategies for hazard prevention (Adeboye, 2025). While these efforts are commendable, their impact at the grassroots, especially among welders in Niger State, remains largely unmeasured. It is based on this that the present study sought to investigate the mechanisms for improving the adoption of safety practices among arc welders in Niger State, Nigeria.

Statement of the Problem

Welding is one of the most hazardous occupations in the informal sector, exposing workers to multiple risks such as burns, radiation, electric shocks, respiratory disorders, and ocular injuries. Despite global awareness of these dangers, evidence shows that welders in developing countries, including Nigeria, continue to experience high rates of work-related injuries and illnesses due to poor adoption of safety practices (Ekefre *et al.*, 2024). The International Labour Organization (ILO, 2022) has repeatedly stressed that occupational accidents and diseases are preventable when effective safety practices and protective equipment are consistently adopted.

However in Nigeria, the welding sector is largely dominated by artisans in the informal economy, where safety regulations are weak, and training is often acquired through apprenticeships that rarely emphasize occupational safety (Ugwu & Adamu, 2023). Adeniyi and Isah (2023) observed that although many welders are aware of workplace hazards, adherence to the use of Personal Protective Equipment (PPE) and other safety measures remains grossly inadequate. Similarly, Obboh and Ofagbor (2022) reported that while nearly all welders in Port Harcourt acknowledged the risk of eye injuries, only 15.3% wore protective eyewear at the time of injury.

The persistence of unsafe practices is further compounded by structural challenges such as the high cost and discomfort of PPE, profit-driven attitudes that discourage investment in safety, and weak enforcement of occupational health regulations (Atulomah & Udoetuk, 2022). In Niger State, where arc welding is a common economic activity and workshops are often located in densely populated urban centers, unsafe practices not only endanger welders but also expose clients and pedestrians to preventable risks. The lack of empirical data on the specific challenges limiting the adoption of safety practices among arc welders, as well as effective strategies to improve compliance, presents a significant research gap. This study therefore sought to investigate the **mechanisms for improving the adoption of safety practices among arc welders in Niger State, Nigeria.**

Aim and Objectives of the Study

The aim of the study was to determine the mechanism for improving the adoption of safety practices among arc welders in Niger State, Nigeria. Specifically, the study sought to;

1. Determine the challenges affecting the adoption of safety practices among arc welders in Niger State, Nigeria.
2. Examine the mechanisms for improving the adoption of safety practices among arc welders in Niger State, Nigeria

Research Questions

The following research questions guided the study:

1. What are the challenges affecting the adoption of safety practices by arc welders in Niger State, Nigeria?
2. What are the mechanisms for improving the adoption of safety practices among arc welders in Niger State, Nigeria?

Hypotheses

The following null hypotheses were tested at 0.05 level of significance:

- H₀₁:** There is no significant difference between the mean responses of highly experienced and moderately experienced arc welding craftsmen regarding the challenges affecting the adoption of safety practices by arc welders in Niger State, Nigeria.
- H₀₂:** There is no significant difference between the mean responses of highly experienced and moderately experienced arc welding craftsmen regarding the mechanisms for improving the adoption of safety practices among arc welders in Niger State, Nigeria.

Methodology

A descriptive survey research design was adopted for this study. According to Shodeinde and Odumosu (2018), a descriptive survey research design involves the use of questionnaires to collect data from a sample that represents a larger population, thereby allowing the findings to be generalized. The target population for the study consisted of 5,600 respondents: 2,200 highly experienced arc welding master craftsmen and 3,400 moderately experienced arc welding master craftsmen drawn from the three senatorial zones of Niger State. A proportional stratified random sampling technique was employed to select 560 respondents (10% of the population), comprising both highly experienced and moderately experienced arc welding master craftsmen across the three senatorial zones of Niger State. Data were collected using a well-structured questionnaire

consisting of 56 items designed to elicit information from the respondents for the purpose of generalization. All items in the questionnaire were structured on a four-point rating scale. The instrument was validated by three experts in the field and pilot-tested using a randomly selected sample of 10 experienced arc welders in the Federal Capital Territory, Abuja. The internal consistency of the questionnaire was determined using the Cronbach Alpha method. The reliability coefficients of the two clusters of the instrument were 0.85, and 0.74, respectively, with an overall reliability coefficient of 0.80. This indicates that the instrument was reliable for use in the study. Data collected were organized and analyzed based on the research questions and null hypotheses formulated for the study. The Statistical Package for the Social Sciences (SPSS, version 27) was employed for analysis. Mean and standard deviation were used to answer the research questions, while z-test statistics were applied to test the null hypotheses at the appropriate level of significance.

Research Question One

What are the challenges affecting the adoption of safety practices by arc welders in Niger state? The data for answering research question one is presented in Table 1.

Table 1: Mean and Standard Deviation of Respondents on the Challenges Affecting the Adoption of Safety Practices among Arc Welders in Niger State

S/N	Item	$\bar{x}$ N=530	SD	Remark
1	Unethical practices of welders due to human attitudinal peculiarities and traditional believes.	3.75	0.70	SA
2	Unsafe practices of welders due to religious assertions	2.49	0.42	D
3	Inadequate engagement of safety managers and ineffective supervision in welding workshops.	2.54	0.70	A
4	Insufficient instructions about the working condition and environment.	2.25	0.70	D
5	Carelessness and over-confidence of welders	2.75	0.70	A
6	Safety wears are not compatible to work with.	3.50	0.43	SA
7	Welders lack of understanding about the workplace safety rules.	3.00	0.86	A
8	Ineffective communication between health and safety managers and workers.	2.99	0.86	A
9	Adaptability of workers to safety practices as it was against the traditional practices.	3.00	0.86	A
10	Lack of proper training on effective use of safety wears.	2.50	0.70	A
11	Operatives' engagement in improper conduct that could endanger theirsafety.	2.50	0.70	A
12	Lack of proper knowledge on the hazards management.	2.50	1.08	A
Table 1 Continues				
13	Low level of compliance with occupational health and safety regulations	3.24	0.82	A
14	Weak national health and safety organization standards	2.50	0.83	A
15	Lack of adequate information on Health and Safety organization	3.50	0.50	SA
16	Weak legal structures on welding activities	2.24	0.83	D
17	Awareness and proper medium of information dissemination	2.99	0.83	A
18	Lack of funding for inspecting health and safety plan in welding firms	2.00	1.13	D
19	Provision of safety facilities	2.50	0.82	A
20	Absence of safety representatives in the workshop	2.50	0.70	A
21	Safety and health audits and inspections by the	1.75	0.83	

	government.			D
22	Insufficient health and safety resources.	2.74	0.70	A
23	Lack of training facilities for stakeholders	2.50	1.09	A
24	Inadequate government regulations and policies.	2.52	0.83	A
25	Lack of knowledge regarding safety and health between welders and employers.	2.50	0.70	A
26	Lack of workers' positive response to wearing PPE.	2.40	0.43	D
27	The inattention of management to the safety program.	2.50	0.70	A
28	Inadequate understanding of workshop safety and regulations.	2.74	0.70	A
29	Conflicting safety and Health activities to specialized professionals.	1.50	0.70	D
30	Welders usually under the influence of drugs or alcohol.	2.00	0.43	D
	Grand Mean/SD	2.61	0.73	Agreed

Note: N = Number of respondents; $\bar{x}$ = mean; SD = Standard Deviation; Strongly Agree (SA); Agree (A); Disagree (A); Strongly Disagree (SD)

Table 1 shows the mean responses of the respondents on thirty (30) items posed to determine the challenges affecting the adoption of safety practices by arc welders with grand mean of 2.61. This implies that most of the arc welding craftsmen agreed with the challenges affecting the adoption of safety practices among arc welders. The standard deviation of the items ranges from 0.42-1.13 which is less than 1.96 meaning the respondents were not too far from the mean and were close to one another in their responses. This closeness of the respondents add value to the reliability of the mean.

Research Question Two

What are the mechanisms for improving the adoption of safety practices among arc welders in Niger State?

The data for answering research question two is presented in Table 4.5.

Table 2: Mean and Standard Deviation of Respondent on the Mechanisms for Improving the Adoption of Safety Practices among Arc Welders

S/N	Item	$\bar{x}$ N=530	SD	Remark
1	Provision of personal protective equipment	3.00	0.10	A
2	Provide first aid supplies	2.74	1.09	A
3	Use of arc welding codes of practice	3.24	1.09	A
4	Training of all the stakeholders	3.49	0.86	A
5	Communication of practices policy and programs to welders	2.74	1.30	A
6	Deal with all hazards promptly	2.74	0.82	A
7	Enforcement of rules and regulations	2.25	0.82	D
8	Risk awareness	2.50	0.50	A
9	Safety inspection of welding facilities	2.74	0.43	A
10	Keeping safety procedures updated	3.00	1.00	A
Table 2 Continues				
11	Meeting fire safety standard rules	2.50	0.50	A
12	Strategic safety communication	3.24	0.83	A

13	Display safety information clearly	2.50	0.50	A
14	Worksite organization to a specific standard	3.50	0.50	SA
15	Routine check on plant and equipment for welding	2.74	1.30	A
16	Emphasizing daily consciousness of safety practice on site	2.50	0.50	A
17	Deduction of wages of workers who failed to use PPE	3.00	0.70	A
18	Daily health and safety briefing at work	2.50	0.50	A
19	Obtaining safety clearance before start of work	3.25	0.43	A
20	Inclusion of safety matters from the planning phase	2.49	1.11	D
21	Assigning safety responsibility to all levels	2.74	0.82	A
22	Reward workers that exhibit excellent safety performances	3.00	0.70	A
23	Allocate budget for safety management	2.25	1.30	D
24	Conduct in-house safety training	2.99	0.70	A
25	Distribute pocket size copy of safety ethics to workers	2.25	0.82	D
26	Institute safety awards to motivation workers.	3.00	0.70	A
Grand Total Mean/SD		2.80	0.76	Agreed

Note: N = Number of respondents; $\bar{x}$ = mean; SD = Standard Deviation; Strongly Agree (SA); Agree (A); Disagree (D); Strongly Disagree (SD)

Table 2 shows the mean responses of the respondents on twenty six (26) items posed to determine the mechanisms for improving the adoption of safety practices among arc welders in Niger State with grand mean of 2.80. This implies that most of the arc welding craftsmen agreed with the items to be the strategies that could be adopted to enhance the adoption of safety practices. The standard deviation of the items ranges from 0.10-1.30 which is less than 1.96 meaning the respondents were not too far from the mean and were close to one another in their responses. This closeness of the respondents add value to the reliability of the mean.

Hypothesis One

There is no significant difference between the mean responses of highly experienced and moderately experienced arc welding craftsmen regarding the challenges affecting the adoption of safety practices among arc welders in Niger State.

The data for testing hypothesis one is presented in Table 3.

Table 3: Two Independent Samples Z-Test Results of the Respondents on the Challenges Affecting the Adoption of Safety Practices among Arc welders

Groups	N	df	$\bar{x}$	SD	Sig. (2-tailed)	Remark
Highly Experienced Arc Welders	210	528	2.50	0.14		
Moderately Experienced Arc Welders	320	2.75	2.30	0.15	1.00	NS

(P>0.05) NS = Not Significant

Table 3 revealed that there was no significant difference ($P > 0.05$) in the mean responses of the respondents. These data supported the hypothesis, $df = 528$; 2-tail = 0.78. The mean and standard deviation for highly experienced arc welders were 2.50 and 0.14. The mean and standard deviation for moderately experienced arc welders were 2.30 and 0.15 respectively. The p-value of the z-test was 1.00 which is greater than the bench mark of 0.05, implying that there was no significant difference in the mean responses of respondents. Hence, hypothesis one was retained. This implies that there was no significant difference in the mean responses of highly experienced and moderately experienced arc welding craftsmen regarding the challenges affecting the adoption of safety practices among arc welders in Niger State.

Hypothesis Two

There is no significant difference between the mean responses of highly experienced and moderately experienced arc welding craftsmen regarding the mechanisms for improving the adoption of safety practices among arc welders in Niger State.

The data for testing hypothesis two is presented in Table 4.

Table 4: Two Independent Samples Z-Test Results of the Respondents on the Mechanisms for Improving the Adoption of Safety Practices among Arc Welders

Groups	N	df	$\bar{x}$	SD	Sig. (2-tailed)	Remark
Highly Experienced Arc Welders	210	528	2.97	0.77		
Moderately Experienced Arc Welders	320	2.75	3.00	0.57	0.93	NS

($P > 0.05$) NS = Not Significant

Table 4 revealed that there was no significant difference ($P > 0.05$) in the mean responses of the respondents. These data supported the hypothesis, $df = 528$; 2-tail = 0.93. The mean and standard deviation for highly experienced arc welders were 2.97 and 0.77. The mean and standard deviation for moderately experienced arc welding were 3.00 and 0.57 respectively. The p-value of the z-test was 0.93 which is greater than the bench mark of 0.05, implying that there was no significant difference in the mean responses of respondents. Hence, hypothesis two was retained. This means that there was no significant difference in the mean responses of highly experienced and moderately experienced arc welding craftsmen regarding the mechanisms for improving the adoption of safety practices among arc welders in Niger State.

Findings of the Study

1. The challenges affecting the adoption of safety practices among arc welders in Niger state includes; unethical practices of welders, lack of proper knowledge on hazards management, absence of safety representatives and lack of information on health and safety among others.

2. The mechanisms for improving the adoption of safety practices among arc welders in Niger State includes: provision of personal protective equipment, training of all stakeholders, display of safety information, strategic safety communication, and conducting in-house training for welders among others.
3. There was no significant difference in the mean responses of highly experienced and moderately experienced arc welding craftsmen regarding the challenges affecting the adoption of safety practices by arc welders in Niger State.
4. There was no significant difference in the mean responses of highly experienced and moderately experienced arc welding craftsmen regarding the mechanisms for improving the adoption of safety practices among arc welders in Niger State.

Discussion of Findings

The findings of the study were discussed in the order of the research questions and hypotheses formulated for the study.

Findings on research question one revealed that the challenges affecting the adoption of safety practices among arc welders in Niger state includes; unethical practices of welders, lack of proper knowledge on hazards management, absence of safety representatives and lack of information on health and safety among others. Also, findings on hypothesis one revealed that there was no significant difference in the mean responses of highly experienced and moderately experienced arc welding craftsmen regarding the challenges affecting the adoption of safety practices by arc welders in Niger State. This implies that both groups of craftsmen regardless of their level of experience share similar views regarding the challenges affecting the adoptions of safety practices by arc welders. This further implies that both group of respondents agreed with the challenges affecting the adoption of safety practices, hence the similarity in their responses.

The findings is in conformity with the findings of Efeeloo (2017) who opined that unethical practices of welders due to human attitudinal peculiarities and traditional believes and safety wears not been compatible to work with among others were agreed by the respondents to be challenges affecting the adoption of safety practices by arc welders. The findings conducted by Adamu *et al.* (2022) gave credence to the findings of this study. However, the respondents disagreed with insufficient instructions about the working condition and environment and unsafe practices of welders due to religious assertions (Benedict and Terzungwe, 2017). This could be as a result of the findings of Efeeloo (2017) who observe that weak legal structures on welding activities and lack of workers' positive response to wearing PPE amongothers were agreed as not been challenges affecting the adoption of safety practices as supported by the researcher. Null hypothesis four of no significant difference was therefore upheld for the two groups. The implication of this is that the respondents did not differ significantly in their opinions on the 30 items. The findings of the study on hypothesis four was in line with the findings of Adamu *et al.* (2022) where it was found out that there was no significance difference in the mean ratings of the responses of highly experienced and moderately experienced arc welding craftsmen. The findings of Adamu *et al.* (2022) gave credence to the findings of this study on hypothesis four.

Furthermore, findings on research question two revealed that the mechanisms for improving the adoption of safety practices among arc welders in Niger State includes: provision of personal protective equipment, training of all stakeholders, and display of safety information, strategic safety communication, and conducting in-house training for welders among others. Findings on it corresponding hypothesis also revealed that there was no significant difference in the mean responses of highly experienced and moderately experienced arc welding craftsmen regarding the strategies that could be adopted to enhance the adoption of safety practices among arc welders in Niger state. This implies that both group of respondents agreed with the techniques that could be adopted to enhance the adoption of safety practices, hence the similarity in their responses. It also implies that both groups of craftsmen regardless of their level of experience share similar views regarding the mechanisms for improving the adoption of safety practices among arc welders in Niger State.

The findings is in conformity with the findings of Zakiul *et al.* (2019) who opined that worksite organization to a specific standard, training of all the stakeholders, strategic safety communication among others were agreed by the respondents to be the mechanisms for improving the adoption of safety practices among arc welders in Niger State. Muhammad *et al.* (2021) further gave credence to the findings of this study, however the respondents disagreed with enforcement of rules and regulations as well as inclusion of safety matters from the planning phase (Francis, 2020). The stand of the respondents could have stemmed from the findings of Zakiul *et al.* (2019) who observe that allocating budget for safety management among others were agreed as not been techniques that could be adopted to enhance the adoption of safety practices as supported by the researcher. Null hypothesis two of no significant difference was therefore upheld for the two groups. The implication of this is that the respondents did not differ significantly in their opinions. Generally, the findings of the study on hypothesis two was in line with the findings of Zakiul *et al.* (2019) where it was found out that there was no significance difference in the mean ratings of the responses of highly experienced and moderately experienced arc welding craftsmen. The findings of Muhammad *et al.* (2021) gave credence to the findings of this study on hypothesis five.

Conclusion

This study found that the major challenges limiting the adoption of safety practices among arc welders in Niger State include unethical work habits, poor knowledge of hazard management, absence of safety representatives, and inadequate health and safety information. To address these issues, mechanisms such as provision of personal protective equipment, regular training, effective safety communication, and in-house safety programmes were identified. Strengthening safety culture through these measures will reduce occupational risks, enhance productivity, and protect both welders and the public.

Recommendations

The following recommendations were made for implementation based on the findings of this study:

1. Arc welding master craftsmen should work on tackling the identified challenges affecting the adoption of safety practices by arc welders in Niger state by providing clear safety guidelines in workshops in order to improve awareness and compliance with safety practices.

2. Government should organize frequent in-house training sessions for welders to reinforce safe practices, address unethical behaviour and ensure adherence to occupational health and safety standards.

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IMPACT OF VIRTUAL LEARNING PLATFORM IN ADDRESSING LARGE CLASS ISSUE AS PERCEIVED BY BIOLOGY EDUCATION STUDENTS IN FEDERAL UNIVERSITY DUTSIN-MA, KATSINA STATE, NIGERIA

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Abstract

The study assessed the Impact of Virtual Learning Platform in Addressing Large Class Issue as Perceived by Biology Education Students in Federal University Dutsin-Ma, Katsina State, Nigeria. The study set four objectives with corresponding research questions and null hypothesis. The study adopted a descriptive survey research design. The population of the study comprised of all Biology students in Federal University Dutsinma, Katsina state with total number of three hundred and seventy-three students (373). 100 Biology education students were randomly selected for the study. Forty item self-structured questionnaire tagged questionnaire for Virtual learning was used as instrument for collection of data using likert rating scale of strongly agree (SA), agree (A), Disagree (D), and Strongly Disagree (SD). The instrument was validated by expert from science education department, Federal University Dutsin-Ma. Finding shows that Virtual learning have significant impact on the reducing the effect of class size in Federal University Dutsin-Ma, there is no significant difference in the opinions of male and female respondents on the effect of class size on academic performance of biology students of Federal University Dutsin-Ma and there is a significant gender differences in the academic performance of Biology education students when exposed to small class size in favour of male students. Based on the findings, recommendations were made which include: there is need for a reform in laws discouraging to reconsider building more classes to avoid large population of Students in class, ICT facilities and training should be available to both lecturers and students in order to benefit from virtual learning, Universities management should organize workshops, seminars or conference where the both students and lecturers can be enlightened on the relevance of entering into virtual learning.

Key note: *Virtual Learning Platform, Large Class Issue, Biology Education Students and Federal University Dutsin-Ma*

Introduction

The population of students applying to tertiary institutions in every country particularly in Nigeria is on the increase as observed by the researchers. This is because education is the best legacy that every parent or every nation of the world can give to her citizen. Access to education may likely make individual within the society to be useful to themselves and to the society at large. In the same vein, access to quality and productive education may be hindered by overcrowded students in the class if not properly controlled. Contemporary educators need to integrate information and communication technology to solve some challenges confronting education. Part of these technologies that could be adopted is 'Virtual Learning Technology'.

Learning is acquisition of knowledge, skills and experience that may lead to change in behavior. Learning as defined by Bello, (2020). Is a process that leads to change, which occurs as a result of experience and increases the potential for improved performance and future learning. The importance of learning is that it helps the individual to acquire the necessary skills and knowledge so that one can achieve the set objective. An important fact about learning is that it is a means to improve knowledge and gain skills that will help in reaching specific goals. Learning is the process of acquiring new understanding, knowledge, behaviors, skills, values, attitudes, and preferences that lead to change in behavior Richard, (2015). Virtual Learning is defined as the learning acquired through interaction with computer and other information and communication technology hardware and software that are relatively based on open systems. This type of learning allows interactions and encounters with other participants and providing access to a wide range of resources Pelet & Lacarte, (2012). Virtual learning by Abdullah, et al, (2013). Referred to an online classroom and a social space in schools that contains a calendar, social networks, shared workspace and online assessment. Virtual learning is a software tool that supports the management of education and teaching by using the internet Trafford & Shirota, (2011). The virtual learning platform is more comprehensive compared to computer-aided instructions (CAI) as it contains the communication dimension as well as interaction and discussions between teachers and students or among students Piccoli et al., (2001). Virtual learning has been used synonymously with the concept such as e-learning, online learning, distance learning or web-based learning (Omiola, & Ojeleye, 2020). Virtual learning expands the possibility of using internet facilities, platforms, satellite links, and related system to access, analyze, create, exchange, use data, get information, and knowledge in ways which until recently, were almost unimaginable. In fact, it involves learning acquired by students through the interaction of digitally delivered content. It involves network-based inputs and tutoring support obtained on online tool and media such as internet, intranets, extranets, simulations, games, virtual worlds, clouds, satellite broadcasts and web platforms (Jarmon, 2013).

Class size refers to the number of students in a given course or classroom, specifically either the number of students being taught by individual teachers in a course or classroom or the average number of students being taught by teachers in a school, district, or education system. The term may also extend to the number of students participating in learning experiences that may not take place in a traditional classroom setting, or it may also refer to the total number of students in a particular class in a school. It should be noted that schools, districts, state and federal education agencies commonly track and report “average class sizes.” While average class sizes are commonly expressed as a ratio of students to teachers. A class above fifty students in the class may be termed as a ‘large class’ Kokkelenberg. (2008).

Fewer studies still have examined the impact of class size on student performance in higher education. Bandiera, (2009). Examines administrative records from a leading UK university and find a significant negative, but highly non-linear effect of class size on student tests results. They conclude that changes in class size have a significant impact on student performance but only at the very top and bottom of the class size distribution. Furthermore, it was reported that students at the top of the grade distribution are most negatively affected by class size, particularly in large class sections. Similarly, Kokkelenberg, (2008). Find that average grades decline significantly with class size at a public northeastern U.S. University. The finding reports that grades drop dramatically with class size up to twenty students.

The larger the class the greater the instructor effort devoted to class wide activities at the expense of individual attention. In this way, individual student learning and outcomes decline as class size increases. His model illustrates the importance of separating class size effects from total student responsibilities effects. Lazear, (2001). Outlines a theoretical model where class size itself is important due to the role that class size plays in setting the class room environment. Large classes (more students) may allow students to be more disruptive, allow them to “hide” from participation, engagement, or even attendance, while small classes may more easily lend themselves to pedagogical activities that improve learning, such as hands on activities and student-faculty classroom interaction.

Based on the researchers’ observation, there many courses in the tertiary institutions where lecturers and students experience challenge regarding the issue of large crowd. Most especially the general courses that are compulsory for all students. In the same vain, the interaction made with some tertiary institution students on the negative effect of overcrowded of students for lecture revealed that, it has a negative effect because it reduces the overall performance of the students while the students find it difficult to achieve the objective of the lessons. It is as a result of this, that the researchers seek to find out the impact of virtual learning platform in addressing class size issue as perceived by students of Federal University Dutsin-Ma. Katsina State, Nigeria.

Statement of the Problem

In recent years, the increasing enrollment of students in tertiary institutions, including Federal University Dutsin-Ma in Katsina State, Nigeria, has led to a rise in large class sizes. This phenomenon poses significant challenges, particularly in specialized fields such as Biology Education, where personalized instruction is crucial. The advent of virtual learning platforms offers a potential solution to address the issues associated with large class sizes. However, the effectiveness and impact of these platforms, specifically in the context of Biology education students at Federal University Dutsin-Ma, remain largely unexplored.

The persistent problem of large class sizes in science education courses raises concerns about the quality of education and the ability of students to actively engage with course content. The problem statement, therefore, revolves around the lack of comprehensive insights into how virtual learning platforms can serve as a viable strategy to mitigate the challenges posed by large class sizes in Biology Education at Federal University Dutsin-Ma. It is imperative to explore the perceptions of Biology Education students regarding the impact of virtual learning platforms on their learning experiences within the context of large class settings. This includes understanding whether virtual platforms effectively address issues such as limited interaction with instructors, reduced opportunities for practical engagement, and the overall quality of education.

To bridge this knowledge gap, this study aims to investigate the impact of virtual learning platforms from the perspective of Biology education students at Federal University Dutsin-Ma, offering valuable insights that can inform educational strategies, policy development, and the enhancement of teaching and learning experiences in the face of growing class sizes.

Purpose of the Study

The main purpose of this study will be to determine the impact of virtual learning platform in addressing class size issue as perceived by students of Federal University Dutsin-Ma, Katsina State, Nigeria. Specifically, the study determines:

1. To determine the impact of virtual learning platform in addressing class size among biology students of Federal University Dutsin-Ma.
2. To examine the effect of class size on academic performance of biology education students of Federal University Dutsin-Ma.
3. To find out gender differences in the academic performance of senior secondary school students in biology when exposed to small class size.

Research Questions

The following questions are used to guide the conduct of this study:

1. What is the impact of virtual learning platform in addressing class size among biology students of Federal University Dutsin-Ma?
2. What is the effect of class size on academic performance of biology students of Federal University Dutsin-Ma?
3. What is the gender differences in the academic performance of senior secondary school students in biology when exposed to small class size?

Hypotheses

H₀₁: There is no significant difference impact of virtual learning platform in addressing class size among biology students of Federal University Dutsin-Ma.

H₀₂: There is no significant difference in the opinions of male and female respondents on the effect of class size on academic performance of biology students of Federal University Dutsin-Ma.

H₀₃ There is no significant gender differences in the academic performance of senior secondary school students in biology when exposed to small class size.

Methodology

The study employed descriptive survey design. The population of the study comprises all Biology students in Federal University Dutsinma, Katsina state. However, from the survey carried by researcher it was revealed that there are three hundred and seventy-three students (373). A sample size of 100 students were selected using simple random sampling technique. a self- structured questionnaire were used as instrument for data collection, the questionnaire were consist of 35 - item instrument, tailored around the modified Likert scale thus for each item, respondents were Strongly Agree (SA), Agree (A), Disagree (D) or Strongly Disagree (SD). The questionnaire was made up of five Sections A, B, C, D and E. Section A were comprise items on the demographic data of respondents while section B, C, D and E were consist Research questions raise to guide the study. The instrument was validated by expert from science education department, Federal University Dutsin-Ma. Descriptive statistics in form of frequency and percentage was used describe the demographic data of the respondents and answer to the research questions while the inferential statistics of Chi-square and t-test independent sample to test the hypotheses at 0.005 level of significance.

Results

Demographic Data of the Respondents

Table 1: Gender of Respondents

Gender	Frequency	Percentage (%)
Male	50	50%
Female	50	50%
Total	100	100%

Source: Questionnaire Field Work, 2024

Table 1 above shows that (50%) of the respondents are male, while female respondents constituted 50%. This shows that respondents are equal.

Table 2: Ages of the Respondents

Age	Frequency	Percentage (%)
18-20 years	70	70%
20-30years	25	25%
40 years above	5	5%
Total	100	100%

Source: Questionnaire Field Work, 2024

Table 2 above shows that majority of the respondents are between the ages of 18-20 and they constitutes (70%), followed by those between the age of 20-30 who constituted (25%) of the respondents, while those that falls between 40-above years constitutes (5%) of the respondents. Therefore, the above shows that majority of the respondents are between 18-20 years. This indicated that majority of the respondents are young.

Table 3: Religion of Respondents

Religion	Frequency	Percentage (%)
Islam	50	50%
Christianity	45	45%
Others	5	5%
Total	100	100%

Source: Questionnaire Field Work, 2024

Table 3 above shows that majority (50%) of the respondents are Muslims, followed by Christians, who are (45%), while those who practice religion aside Islam and Christianity constitutes (5%) of the retrieved data. This shows that majority of the respondents are Muslims.

Table 4: Tribe of Respondents

Tribe	Frequency	Percentage (%)
Hausa	40	40%
Igbo	25	25%
Yoruba	30	30%
Others	5	5%
Total	100	100%

Source: Questionnaire Field Work, 2024

Table 4 above shows that majority (40%) of the respondents were Hausa by tribe, this is followed by those on the category of others which constituted (25%), while Igbo and Yoruba constituted (30%) and (5%) respectively.

Research Questions 1: What is the impact of virtual learning platform in addressing class size among biology students of Federal University Dutsin-Ma?

Table 5: Virtual learning have significant impact on the reducing the effect of class size in Federal University Dutsin-Ma

S/N	ITEMS	FREQUENCY (NO)	PERCENTAGE (%)
1.	A	33	33
2.	SA	10	10
3.	D	17	17
4.	SD	40	40
Total		100	100

Source: Questionnaire Field Work, 2024

From the table 5 above shows that, 33 respondents representing 33% of the total respondents agreed with the statement, that Virtual learning have significant impact on the reducing the effect of class size in Federal University Dutsin-Ma, 10 respondent representing 10% strongly agreed with the statement while 17 respondents representing 17% of the total respondents disagreed with the statement that Virtual learning have significant impact on the reducing the effect of class size in Federal University Dutsin-Ma, and 40 respond for the option strongly disagree representing 40% respectively. This reveals that the majority of the respondents agreed with the statement that Virtual learning have significant impact on the reducing the effect of class size in Federal University Dutsin-Ma.

Table 6: Virtual learning contributed in reducing the damaged caused by class size and large population of students in Federal University Dutsin-Ma

S/N	RESPONSE	FREQUENCY (NO)	PERCENTAGE (%)
1.	A	30	30
2.	SA	30	30
3.	D	20	20
4.	SD	20	20
Total		100	100

Source: Questionnaire Field Work, 2024

From the table 6 above shows that, 30 respondents representing 30% of the total respondents agreed with the statement, Virtual learning contributed in reducing the damaged caused by class size and large population of students in Federal University Dutsin-Ma, 30 respondent representing 30% strongly agreed with the statement while 20 respondents representing 20% of the total respondents disagreed with Virtual learning contributed in reducing the damaged caused by class size and large population of students in Federal University Dutsin-Ma, and 20 respond for the option strongly disagree representing 20% respectively. This reveals that the majority of the respondents agree and strongly agree with the statement that Virtual learning contributed in reducing the damaged caused by class size and large population of students in Federal University Dutsin-Ma.

Table 7: Students in Federal University Dutsinma can attends lectures conveniently due to the introduction of virtual platform

S/N	RESPONSE	FREQUENCY (NO)	PERCENTAGE (%)
1.	A	45	45
2.	SA	25	25
3.	D	17	17
4.	SD	13	13
Total		100	100

Source: Questionnaire Field Work, 2024

From the table 7 above shows that, 45 respondents representing 45% of the total respondents agreed with the statement, Students in Federal University Dutsinma can attends lectures conveniently due to the introduction of virtual platform, 25 respondent representing 25% strongly agreed with the statement while 17 respondents representing 16% of the total respondents disagreed with Students in Federal University Dutsinma can attends lectures conveniently due to the introduction of virtual platform and 13 respond for the option strongly disagree representing 13% respectively. This reveals that the majority of the respondents agree and strongly agree with the statement Students in Federal University Dutsinma can attends lectures conveniently due to the introduction of virtual platform.

Table 8: Virtual learning have negative impact on the students' academic performance in Federal University Dutsin-Ma

S/N	RESPONSE	FREQUENCY (NO)	PERCENTAGE (%)
1.	A	30	30
2.	SA	50	50
3.	D	10	10
4.	SD	10	10
Total		100	100

Source: Questionnaire Field Work, 2024

From the table 8 above shows that, 30 respondents representing 30% of the total respondents agree with the statement Virtual learning have negative impact on the students' academic performance in Federal University Dutsin-Ma, 50 respondent representing 50% strongly agreed that Virtual learning have negative impact on the students' academic performance in Federal University Dutsin-Ma while 10 respondents representing 10% of the total respondents disagreed with Virtual learning have negative impact on the students' academic performance in Federal University Dutsin-Ma, and 10 respond for the option strongly disagree representing 11% respectively. This reveals that the majority of the respondents agreed and strongly agreed that Virtual learning have negative impact on the students' academic performance in Federal University Dutsin-Ma.

Research Questions 2: What is the effect of class size on academic performance of biology students of Federal University Dutsin-Ma?

Table 9: Class room size have negative effect on the students' academic performance in Federal University Dutsinma

S/N	RESPONSE	FREQUENCY (NO)	PERCENTAGE (%)
1.	A	28	28
2.	SA	12	12
3.	D	16	16
4.	SD	44	44
Total		100	100

Source: Questionnaire Field Work, 2024

From the table 9 above shows that, 28 respondents representing 28% of the total respondents agreed with the statement, Class room size have negative effect on the students' academic performance in Federal University Dutsinma, 12 respondent representing 12% strongly agreed with the statement while 16 respondents representing 16% of the total respondents disagreed with Class room size have negative effect on the students' academic performance in Federal University Dutsinma, and 44 respond for the option strongly disagree representing 11% respectively. This reveals that the majority of the respondents agreed and strongly agreed with the statement that, Class room size have negative effect on the students' academic performance in Federal University Dutsinma.

Table 10: Class room size have positive effect on the students' academic performance in Federal University Dutsinma

S/N	RESPONSE	FREQUENCY (NO)	PERCENTAGE (%)
1.	A	19	19
2.	SA	37	37
3.	D	25	25
4.	SD	19	19
Total		100	100

Source: Questionnaire Field Work, 2024

From the table 10 above shows that, 19 respondents representing 19% of the total respondents agreed with the statement, Class room size have positive effect on the students' academic performance in Federal University Dutsinma, 37 respondent representing 37% strongly agreed with the statement while 25 respondents representing 25% of the total respondents disagreed with Class room size have positive effect on the students' academic performance in Federal University Dutsinma, and 19 respond for the option strongly disagree representing 19% respectively. This reveals that the majority of the respondents agreed and strongly agreed with the statement that, Class room size have positive effect on the students' academic performance in Federal University Dutsinma.

Table 11: Students ability to understand in class room is reduced due to large population of students in Federal University Dutsinma

S/N	ITEMS	FREQUENCY (NO)	PERCENTAGE (%)
1.	A	28	28
2.	SA	12	12
3.	D	16	16
4.	SD	44	44
Total		100	100

Source: Questionnaire Field Work, 2024

From the table 11 above shows that, 28 respondents representing 28% of the total respondents agreed with the statement, Students ability to understand in class room is reduced due to large population of students in Federal University Dutsinma, 12 respondent representing 12% strongly agreed with the statement while 16 respondents representing 16% of the total respondents disagreed with Students ability to understand in class room is reduced due to large population of students in Federal University Dutsinma and 44 respond for the option strongly disagree representing 44% respectively. This reveals that the majority of the respondents strongly disagreed with the statement that, Students ability to understand in class room is reduced due to large population of students in Federal University Dutsinma.

Table 12: There is need to consider building more classes in Federal University Dutsinma because the poor performance of Biology students

S/N	RESPONSE	FREQUENCY (NO)	PERCENTAGE (%)
1.	A	30	30
2.	SA	50	50
3.	D	9	9
4.	SD	11	11
Total		100	100

Source: Questionnaire Field Work, 2024

From the table 12 above shows that, 30 respondents representing 30% of the total respondents agreed with the statement, There is need to consider building more classes in Federal University Dutsinma because the poor performance of Biology students, 50 respondent representing 50% strongly agreed with the statement while 9 respondents representing 9% of the total respondents disagreed There is need to consider building more classes in Federal University Dutsinma because the poor performance of Biology students, and 11 respond for the option strongly disagree representing 11% respectively. This reveals that the majority of the respondents agreed and strongly agreed with the statement that, There is need to consider building more classes in Federal University Dutsinma because the poor performance of Biology students.

Research Questions 3: What is the gender differences in the academic performance of senior secondary school students in biology when exposed to small class size?

Table 13: Male student's performance better than Female student in secondary school

S/N	RESPONSE	FREQUENCY (NO)	PERCENTAGE (%)
1.	A	50	60
2.	SA	35	35
3.	D	5	5
4.	SD	10	10
Total		100	100

Source: Questionnaire Field Work, 2024

From the table 13 above shows that, 50 respondents representing 50% of the total respondents agreed with the statement, Male students performance better than Female student in secondary school, 35 respondent representing 35% strongly agreed with the statement while 5 respondents representing 5% of the total respondents disagreed with Male students performance better than Female student in secondary school, and 10 respond for the option strongly disagree representing 10% respectively. This reveals that the majority of the respondents agreed and strongly agreed with the statement that, Male student's performance better than Female student in secondary school.

Table 14: Female students always tend to have poor academic performance than Male counter part

S/N	RESPONSE	FREQUENCY (NO)	PERCENTAGE (%)
1.	A	38	38
2.	SA	12	12
3.	D	16	16
4.	SD	34	34
Total		100	100

Source: Questionnaire Field Work, 2024

From the table 14 above shows that, 38 respondents representing 38% of the total respondents agreed with the statement, Female students always tend to have poor academic performance than Male counterpart, 12 respondent representing 12% strongly agreed with the statement while 16 respondents representing 16% of the total respondents disagreed with Female students always tend to have poor academic performance than Male counterpart, and 34 respond for the option strongly disagree representing 34% respectively. This reveals that the majority of the respondents agreed with the statement that, Female students always tend to have poor academic performance than Male counterpart.

Testing Hypotheses

H₀₁: There is no significant impact of virtual learning platform in addressing class size among biology students of Federal University Dutsin-Ma.

Table 15: Chi- Square analysis on impact of virtual learning platform in addressing class size among biology students of Federal University Dutsin-Ma.

	Chi-square	df	P- value	Decision
impact of virtual learning platform in addressing class size among biology students of Federal University Dutsin-Ma	1.00	3	0.801	Significant

Table 15 revealed that the Chi- Square value of 198.89 was computed and the p- value 0.000 was observed. Hence, the study rejected the hypothesis that say there is no impact of virtual learning platform in addressing class size among biology students of Federal University Dutsin-Ma. This implies that the virtual learning platform significantly has impact in addressing class size among biology students of Federal University Dutsin-Ma

H₀₂: There is no significant difference in the opinions of male and female respondents on the effect of class size on academic performance of biology students of Federal University Dutsin-Ma.

Table 16: t-test analysis of the opinions of male and female respondents on the effect of class size on academic performance of biology students

Gender	N	Mean	SD	df	t-value	P-value	Decision
Male	50	18.04	3.323	98	2.897	0.065	Not sign.
Female	50	19.97	1.979				

Table 16 revealed that the t-value computed was 0.917 and the p-value of 0.015 was observed. Since the obtained p-value of 0.065 is greater than the alpha value of 0.05, based on the decision rule, this study retained the says there is no significant difference in the opinions of male and female respondents on the effect of class size on academic performance of biology students of Federal University Dutsin-Ma. The decision implies that, of male and female respondents have the same opinions on the effect of class size on academic performance of biology students of Federal University Dutsin-Ma.

H₀₃: There is no significant gender differences in the academic performance of Biology education students when exposed to small class size.

Table 17: t-test analysis of the gender differences in the academic performance of Biology education students when exposed to small class size

Gender	N	Mean	SD	df	t-value	P-value	Decision
Male	50	21.04	3.323	98	2.897	0.010	Significant
Female	50	19.97	1.979				

Table 16 revealed that the t-value computed was 2.897 and the p-value of 0.015 was observed. Since the obtained p-value of 0.010 is less than the alpha value of 0.05, based on the decision rule, this study rejected the says there is no significant gender differences in the academic performance of Biology education students when exposed to small class size. The decision implies that, there is a significant gender differences in the academic performance of Biology education students when exposed to small class size in favour of male students. This indicated that male students performed significantly better than male students when exposed to small class size.

Conclusion

Based on the finding from the study, it was concluded that Virtual learning have significant impact on the reducing the effect of class size in Federal University Dutsin-Ma, Virtual learning contributed in reducing the damaged caused by class size and large population of students in Federal University Dutsin-Ma and male students performed significantly better than male students when exposed to small class size.

Recommendations

Based on the findings of this study, the researcher recommended that;

1. There is need for a reform in laws discouraging to reconsider building more classes to avoid large population of Students in class.
2. ICT facilities and training should be available to both lecturers and students in order to benefit from virtual learning
3. Universities management should organize workshops, seminars or conference where the both students and lecturers can be enlightened on the relevance of entering into virtual learning.
5. Guidance Counsellors posted in schools should make their impact to be felt; especially in the provision of educational, vocational and personal social services to students,

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ASSESSMENT OF OFFICE FACILITIES FOR BUILDING A SKILLED AND INNOVATIVE WORKFORCE IN THE ERA OF STEAM EDUCATION AND ARTIFICIAL INTELLIGENCE: A CASE STUDY OF FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA (BOSSO CAMPUS)

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Abstract

This study examined the adequacy, challenges, and improvement strategies of office facilities in fostering a skilled and innovative workforce in the era of STEAM education and Artificial Intelligence (AI) at the Federal University of Technology, Minna (Bosso Campus). Guided by three objectives, a descriptive survey design was adopted, and data were collected from 71 academic and non-academic staff using a structured questionnaire. Descriptive statistics (frequency counts, percentages, means, and standard deviations) were used to answer the research questions, while Chi-square and t-test were employed at a 0.05 significance level to test the hypotheses. Findings revealed that office facilities such as furniture, internet connectivity, ICT resources, and power supply were generally inadequate, limiting staff effectiveness and innovation. Major challenges identified included unstable electricity, poor internet service, and inadequate ICT tools. Recommended strategies included provision of ergonomic furniture, stable power supply, reliable internet, and AI-driven digital resources. The study concludes that addressing these gaps is essential to creating an enabling environment for workforce development in the digital era.

Keywords: *Office facilities, STEAM education, Artificial Intelligence, workforce development*

Introduction

The quality and adequacy of office facilities in higher education institutions play a crucial role in enhancing staff productivity, teaching efficiency, and administrative effectiveness. In universities, where academic and administrative staff are responsible for a wide range of tasks, the availability of well-equipped and functional office spaces is essential for smooth institutional operations (Eke & Bufumoh, 2024). Adequate office facilities such as furniture, lighting, ICT equipment, ventilation, and ergonomic arrangements contribute significantly to the efficiency and motivation of staff (Adesina & Shotayo, 2024). Conversely, inadequate or poorly maintained facilities can hinder effective service delivery and limit institutional performance.

In recent years, there has been a global shift towards Science, Technology, Engineering, Arts, and Mathematics (STEAM) education and the integration of Artificial Intelligence (AI) in educational systems, with a strong focus on building a skilled and innovative workforce (Adesina & Shotayo, 2024; Idowu & Ajibade, 2025). Universities are increasingly expected to provide an enabling environment where staff can effectively carry out their teaching, research, and administrative roles in alignment with emerging technological demands. This is particularly relevant in Nigeria, where educational reforms and technological innovations are considered essential to national development and workforce competitiveness (Paul, Dare & Obasi, 2024).

In Nigeria, several recent studies like that of Adesina & Shotayo (2024); Samuel, Ikwuanusi & Okonkwo (2024); Shaibu (2025); have underscored the importance of office/physical facilities and work environment. At the same time, the push for STEAM education (Science, Technology, Engineering, Arts, and Mathematics) and integration of Artificial Intelligence (AI) in Nigerian educational policy and practice is growing. These shifts emphasize interdisciplinary, innovation, digital literacy, and the capacity for staff and institutions to adapt to emerging technologies for effective education delivery.

The integration of AI and digital technologies into university systems requires adequate infrastructural support, including well-equipped office facilities that can foster collaboration, innovation, and creativity (Samuel, Ikwuanusi & Okonkwo, 2024; Ayanwale, Adelana & Odufuwa, 2024). Studies have shown that institutional facilities influence not only job satisfaction but also the ability of staff to engage in research, interdisciplinary projects, and innovative practices that support STEAM education (Bello, Oyelekan, & Alabi, 2024). Hence, assessing the state of office facilities in Nigerian universities, such as the Federal University of Technology, Minna, is essential to understanding the extent to which these facilities support academic staff in driving educational transformation and preparing a technologically skilled workforce.

It becomes important to assess whether the office facilities at institutions are sufficient to support staff in this evolving educational landscape where STEAM education and AI are no longer optional, but critical to developing a skilled and innovative workforce. This study therefore seeks to assess the office facilities among staff of the Federal University of Technology, Minna (Bosso Campus), with particular attention to how these facilities align with the demands of STEAM education and AI-driven workforce development.

Problem Statement

In the era of **STEAM education and Artificial Intelligence (AI)**, universities are expected to provide adequate and functional office facilities that support both academic and administrative productivity. Office facilities such as ergonomic furniture, reliable power supply, modern ICT infrastructure, AI-enabled digital tools, proper lighting, and conducive workspaces are crucial for fostering innovation, effective teaching, efficient research, and responsive administration. The Studies of Bello, Oyelekan, & Alabi (2024), Shaibu (2025) have shown that office environments directly influence staff job satisfaction, efficiency, and creativity. Without such facilities, the drive to build a **skilled and innovative workforce** for the 21st century becomes severely constrained. According to Akpan (2025). Adesina & Shotayo (2024); Idowu & Ajibade (2025) infrastructural deficits such as overcrowded offices, poor internet connectivity, inadequate ventilation, and lack of modern office technologies limit staff productivity and reduce institutional competitiveness. At the Federal University of Technology, Minna (Bosso Campus), anecdotal evidence suggests that lecturers and administrative staff contend with outdated office setups, insufficient ICT tools, and unstable utilities. These deficiencies undermine the integration of AI-driven innovations and the realization of STEAM-aligned workforce goals.

Thus, the problem is twofold: first, the absence of empirical evidence assessing the state of office facilities at FUT Minna (Bosso Campus); and second, the uncertainty over how these facilities influence staff capacity to contribute toward **building a skilled and innovative workforce**. Without addressing these issues, the university risks producing graduates ill-prepared for the

technological, entrepreneurial, and innovative demands of the modern economy. This study is therefore justified in assessing the adequacy, functionality, and challenges of office facilities as a foundation for workforce development in the AI and STEAM era.

Purpose of the Study

The purpose of this study is to assess the **office facilities for building a skilled and innovative workforce in the era of STEAM education and Artificial Intelligence** at the Federal University of Technology, Minna (Bosso Campus). Specifically, the study seeks to:

1. Examine the adequacy and functionality of office facilities available to staff of FUT Minna (Bosso Campus).
2. Identify the major challenges associated with office facilities among staff of FUT Minna (Bosso Campus)?
3. Recommend strategic measures for improving office facilities to create an enabling environment for fostering a skilled and innovative workforce in the university system.

Research Questions

In line with the stated objectives, the study will be guided by the following research questions:

1. What is the level of adequacy and functionality of office facilities available to staff of FUT Minna (Bosso Campus)?
2. What are the major challenges associated with office facilities among staff of FUT Minna (Bosso Campus)?
3. What strategies can be recommended to improve office facilities in order to enhance staff effectiveness and contribute to the development of a skilled and innovative workforce in the era of STEAM education and Artificial Intelligence?

Research Hypotheses

H_{0 1} : There is no significant adequacy and functionality of office facilities available to staff of FUT Minna (Bosso Campus).

H_{0 2} : There are no significant challenges associated with office facilities that hinder staff effectiveness and innovation at FUT Minna (Bosso Campus).

H_{0 3} : There are no significant strategies that can be adopted to improve office facilities for enhancing staff effectiveness and workforce development at FUT Minna (Bosso Campus).

Scope of the Study

This study focused on assessing office facilities at the Federal University of Technology, Minna (FUTMinna), Bosso Campus, with particular attention to the School of Science and Technology Education (SSTE). The population comprised only lecturers and administrative staff across the four departments: Industrial and Educational Technology (ITE), Science Education (SED), Educational Technology (EDT), and Library and Information Science (LIS). The study examined the adequacy and functionality of office facilities. It also investigated challenges associated with these facilities and proposed strategies for improvement in order to foster an enabling environment for building a skilled and innovative workforce in the era of STEAM education and Artificial Intelligence (AI). However, the study was delimited to Bosso Campus alone, excluding dean's office staff and did not include the main campus at Gidan Kwano of the university, which accommodates additional schools, departments, and administrative units with possibly different

office facilities and infrastructural conditions. As such, the findings may not be generalized to the entire university community. Despite this limitation, the study provides meaningful insights into the adequacy and challenges of office facilities within SSTE and highlights areas for improvement that can support workforce development in line with STEAM and AI imperatives.

Results

Research Question One

What is the level of adequacy and functionality of office facilities available to staff of FUT Minna (Bosso Campus)?

S/No	Office Facility	Mean	SD	Remark
1	Office furniture is adequate and comfortable	1.95	0.85	Not Adequate
2	Lighting is sufficient for daily tasks	2.60	0.80	Adequate
3	Ventilation supports a healthy environment	2.80	0.90	Adequate
4	ICT resources are available and functional	1.80	0.80	Not Adequate
5	Internet connectivity is reliable	1.50	0.70	Not Adequate
6	Power supply is stable and reliable	1.20	0.50	Not Adequate
7	Office layout/space enhances productivity	2.30	0.90	Adequate
8	Facilities support STEAM and AI integration	1.80	0.80	Not Adequate
9	Projectors/interactive boards available	2.10	0.85	Not Adequate
10	Adequate storage facilities	2.00	0.90	Not Adequate
11	Ergonomic seating/workstations provided	1.90	0.85	Not Adequate
12	Modern communication tools available	1.75	0.80	Not Adequate
13	Office facilities are regularly maintained	2.25	0.95	Adequate
14	Safety/security measures provided	2.10	0.88	Not Adequate
15	Accessibility of office facilities	2.50	1.00	Adequate

The results in Table 1 reveal the level of adequacy and functionality of office facilities available to staff of FUT Minna (Bosso Campus). The analysis indicates that some facilities such as lighting ($M = 2.60$, $SD = 0.80$), ventilation ($M = 2.80$, $SD = 0.90$), and accessibility ($M = 2.50$, $SD = 1.00$) were rated as adequate, the majority of office facilities including internet connectivity ($M = 1.50$, $SD = 0.70$), ICT resources ($M = 1.80$, $SD = 0.80$), and power supply ($M = 1.20$, $SD = 0.50$) were rated as not adequate. This reveals an infrastructural gap that hinders the integration of STEAM and AI tools in academic and administrative work.

Research Question Two

What are the major challenges associated with office facilities among staff of FUT Minna (Bosso Campus)?

Table 2: Challenges Associated with Office Facilities (N=71)

S/No	Items	Mean	SD	Remark
1	Frequent power outage disrupts office tasks	3.60	0.55	Agree
2	Internet connectivity is unreliable	3.45	0.60	Agree
3	Lack of adequate ICT resources	3.30	0.65	Agree
4	Poor ventilation in offices	2.95	0.70	Agree
5	Lack of ergonomic seating/workstations	3.10	0.75	Agree
6	Inadequate storage facilities	2.85	0.68	Agree
7	Insufficient lighting in some offices	2.80	0.72	Agree
8	Facilities not inclusive for disabled staff	3.00	0.70	Agree
9	Poor maintenance culture	3.20	0.68	Agree
10	Lack of modern communication tools	3.15	0.74	Agree
11	Insufficient safety/security measures	3.05	0.72	Agree
12	Lack of STEAM and AI integration	3.25	0.69	Agree
13	Limited office space reduces productivity	2.90	0.73	Agree
14	Inadequate projectors/interactive boards	3.10	0.71	Agree
15	Irregular maintenance of office furniture	3.20	0.66	Agree

The result in Table 2 highlights that frequent power outages ($M = 3.60$, $SD = 0.55$), unreliable internet connectivity ($M = 3.45$, $SD = 0.60$), and lack of adequate ICT resources ($M = 3.30$, $SD = 0.65$) ranked as the most pressing challenges. Other significant issues include poor maintenance culture ($M = 3.20$, $SD = 0.68$), irregular maintenance of furniture ($M = 3.20$, $SD = 0.66$), lack of modern communication tools ($M = 3.15$, $SD = 0.74$), and inadequate safety/security measures ($M = 3.05$, $SD = 0.72$). These challenges collectively disrupt productivity, reduce efficiency, and obstruct staff capacity to integrate innovative teaching, research, and administrative functions.

Research Question Three

What strategies can be recommended to improve office facilities in order to enhance staff effectiveness and contribute to the development of a skilled and innovative workforce in the era of STEAM education and Artificial Intelligence?

Table 3: Strategies for Improving Office Facilities (N = 71)

S/No	Items	Mean	SD	Remark
1	Provision of reliable/constant power supply	3.70	0.50	Agree
2	Improving internet connectivity and bandwidth	3.65	0.55	Agree
3	Upgrading ICT facilities (computers, projectors, printers)	3.55	0.60	Agree
4	Establishing effective maintenance culture	3.40	0.65	Agree
5	Provision of ergonomic office furniture	3.25	0.70	Agree
6	Provision of adequate lighting systems	3.15	0.72	Agree
7	Expansion of office space	3.05	0.74	Agree
8	Provision of adequate storage facilities	3.20	0.68	Agree
9	Equipping offices with AI-enabled tools	3.30	0.70	Agree
10	Adoption of renewable energy (e.g., solar power)	3.45	0.62	Agree
11	Establishing ICT support units	3.35	0.66	Agree
12	Enhancing STEAM integration in office work	3.25	0.70	Agree
13	Provision of communication tools (VC, conferencing)	3.40	0.64	Agree
14	Enhancing inclusivity for staff with disabilities	3.10	0.72	Agree
15	Regular training on digital/AI tools	3.50	0.60	Agree

The results in Table 3 show that provision of reliable power supply ($M = 3.70$, $SD = 0.50$), improved internet connectivity ($M = 3.65$, $SD = 0.55$), and upgrading ICT facilities ($M = 3.55$, $SD = 0.60$) were rated as the most effective strategies. Other strategies include integration of AI-enabled tools ($M = 3.30$, $SD = 0.70$), adoption of renewable energy ($M = 3.45$, $SD = 0.62$), regular training on digital/AI tools ($M = 3.50$, $SD = 0.60$), and establishment of maintenance culture ($M = 3.40$, $SD = 0.65$). These strategies align with global best practices in creating innovative and future-ready workplaces.

Hypothesis One ($H_{0\ 1}$)

There is no significant adequacy and functionality of office facilities available to staff of FUT Minna (Bosso Campus).

Table 4a: Chi-square Results for Adequacy and functionality of Office Facilities

Variable	df	χ^2	p-value	Decision
Adequacy of office facilities	14	38.45	0.001	Reject $H_{0\ 1}$

Table 4b: T-test Results for Adequacy and functionality of Office Facilities

Variable	df	t	p-value	Decision
Adequacy of office facilities	70	-2.85	0.005	Reject $H_{0\ 1}$

The chi-square test (Table 4a) revealed a significant relationship between adequacy levels and staff responses ($\chi^2 = 38.45$, $p < 0.05$). Similarly, the t-test result (Table 4b) showed a statistically significant difference in the mean adequacy scores compared to the expected mean ($t = 2.85$, $p < 0.05$). Thus, $H_{0\ 1}$ is rejected.

Hypothesis Two ($H_{0\ 2}$)

There are no significant challenges associated with office facilities that hinder staff effectiveness and innovation at FUT Minna (Bosso Campus).

Table 5a: Chi-square Results for Challenges of Office Facilities

Variable	df	χ^2	p-value	Decision
Challenges of office facilities	14	41.20	0.000	Reject $H_{0\ 2}$

Table 5b: T-test Results for Challenges of Office Facilities

Variable	df	t	p-value	Decision
Challenges of office facilities	70	3.15	0.003	Reject $H_{0\ 2}$

Chi-square analysis (Table 5a) indicated a significant association between identified challenges and respondents' perceptions ($\chi^2 = 41.20$, $p < 0.05$). The t-test (Table 5b) further confirmed significant differences in the mean challenge scores ($t = 3.15$, $p < 0.05$). $H_{0\ 2}$ is therefore rejected.

Hypothesis Three ($H_{0\ 3}$)

There are no significant strategies that can be adopted to improve office facilities for enhancing staff effectiveness and workforce development at FUT Minna (Bosso Campus).

Table 6a: Chi-square Results for Strategies to Improve Office Facilities

Variable	df	χ^2	p-value	Decision
Strategies for improvement	14	52.35	0.000	Reject $H_{0\ 3}$

Table 6b: T-test Results for Strategies to Improve Office Facilities

Variable	df	t	p-value	Decision
Strategies for improvement	70	3.45	0.001	Reject $H_{0\ 3}$

Chi-square results (Table 6a) showed significant differences in respondents' agreement on strategies ($\chi^2 = 52.35$, $p < 0.05$). Likewise, the t-test (Table 6b) revealed significant deviations from the expected mean ($t = 3.45$, $p < 0.05$). Therefore, $H_{0\ 3}$ is rejected.

Findings of the Study**RQ1: What is the level of adequacy and functionality of office facilities available to staff of FUT Minna (Bosso Campus)?**

- Office furniture, ICT resources, internet connectivity, power supply, and modern communication tools were generally rated as *not adequate*.
- Lighting, ventilation, office layout, and accessibility for all staff showed *adequacy*.
- Overall, office facilities were found insufficient to support day-to-day operations and hindered full integration of STEAM and AI-based practices.

RQ2: What are the major challenges associated with office facilities among staff of FUT Minna (Bosso Campus)?

- Unstable and unreliable power supply was the most significant challenge. While poor internet connectivity and low ICT capacity restricted effective teaching, research, and administrative work.
- Insufficient ergonomic furniture, inadequate storage, and poor maintenance culture also created obstacles to productivity.
- Lack of modern tools (e.g., projectors, AI-enabled devices, video conferencing facilities) further limited staff innovation and collaboration.

RQ3: What strategies can be recommended to improve office facilities in order to enhance staff effectiveness and workforce development?

- Provision of alternative energy sources (solar, generators) for stable power supply and Implementation of regular maintenance schedules for office facilities.
- Upgrade of ICT infrastructure and internet bandwidth to support AI and STEAM adoption.
- Investment in ergonomic furniture, modern teaching/communication tools, and inclusive designs for staff with disabilities.

- Capacity-building programs and workshops on STEAM and AI to enhance staff competence and innovation.

Discussion of Findings

The findings show that some basic facilities such as lighting and ventilation meet minimum adequacy, critical enablers of STEAM education and AI (e.g., internet, ICT resources, modern communication tools and among others) are significantly inadequate. The hypothesis test confirms that the overall adequacy of office facilities is significantly below expected levels. This implies that the institutional environment may not be conducive to promoting innovation, digital adoption, and workforce readiness. These findings align with Paul, Dare & Obasi (2024); Shaibu (2024); Idowu & Ajibade (2025) who emphasized the centrality of ICT and reliable infrastructure in higher education productivity.

The hypothesis was rejected, showing that the challenges are statistically significant. Staff experience daily obstacles from unreliable power, poor internet services, and inadequate AI-integrated resources. This agrees with Bello, Oyelekan & Alabi (2024); Samuel, Ikwuanusi & Okonkwo (2024); Akpan (2025) who noted that infrastructural deficits remain one of the leading bottlenecks to academic performance and staff efficiency in Nigerian universities. Without addressing these challenges, the integration of STEAM and AI into higher education remains aspirational.

The hypothesis was rejected, confirming that strategic measures such as upgrading infrastructure, expanding ICT access, and embedding AI tools are statistically significant drivers of workforce innovation. This resonates with Eke & Bufumoh (2024); Adesina & Shotayo (2024); Ayanwale, Adelana & Odufuwa (2024) who emphasized that deliberate infrastructural and digital investments are essential for aligning higher education with global 21st-century workforce needs.

Conclusion

This study assessed the office facilities available to staff of the Federal University of Technology, Minna (Bosso Campus) in the context of building a skilled and innovative workforce in the era of STEAM education and Artificial Intelligence. Findings revealed that some facilities are available, many are inadequate, poorly maintained, or non-functional particularly power supply, internet connectivity, and STEAM/AI integration tools. Despite these shortcomings, staff members expressed strong positive attitudes toward the adoption of modern facilities, indicating readiness to embrace innovations if infrastructural support is provided. The study further established significant differences in perceptions between lecturers and administrative staff, with lecturers being more critical of the adequacy of facilities due to their heavy reliance on them for academic tasks. In conclusion, the realization of a skilled and innovative workforce in FUT Minna depends on the provision of adequate, functional, and modern facilities that align with the needs of STEAM education and AI. Addressing these infrastructural gaps will not only improve staff productivity but also position the institution to produce graduates equipped with the skills required to thrive in the 21st-century workforce.

Recommendations

Based on the findings of this study, the following recommendations are made to improve office facilities in the Federal University of Technology, Minna (Bosso Campus):

1. **Improve Power Supply Infrastructure:** The university management should invest in alternative and renewable energy sources such as solar power to address the challenge of unreliable electricity supply, which is critical for ICT use and AI-driven innovations.
2. **Enhance Internet Connectivity:** Reliable and high-speed internet connectivity should be prioritized to support research, teaching, and collaborative learning in line with the demands of STEAM education and AI integration.
3. **Provision and Maintenance of Modern ICT Facilities:** Adequate provision of up-to-date ICT equipment, including computers, projectors, digital whiteboards, and AI-enabled tools, should be ensured. Regular maintenance should also be carried out to guarantee their functionality.
4. **Expansion and Renovation of Physical Facilities:** Lecture theatres, laboratories, and library facilities should be expanded and renovated to accommodate the growing staff and student population, thereby fostering a conducive environment for skill acquisition and innovation.
5. **Capacity Building for Staff:** Regular workshops and training programs should be organized to build staff competencies in the effective utilization of STEAM and AI resources for teaching, research, and administration.

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ARTIFICIAL INTELLIGENCE, TEACHER EDUCATION, AND CAREER DEVELOPMENT IN NIGERIA

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Abstract:

Artificial intelligence (AI) is reshaping education systems globally and presents both opportunities and risks for Nigeria's teacher education and workforce development. This paper synthesizes recent policy directions, empirical evidence, and global competency frameworks to examine how AI can strengthen initial teacher education (ITE), continuous professional development (CPD), and teachers' career pathways in Nigeria. Drawing on Nigeria's 2024 National AI Strategy, UNESCO's 2024–2025 AI competency frameworks for teachers, TRCN professional standards, and new empirical studies—including a 2025 randomized evaluation of AI-powered tutoring in Nigerian secondary schools—we map actionable levers for curriculum redesign, assessment, and credentialing. We propose a Nigerian AI Teacher Competency Map aligned to TRCN standards; a CPD micro-credential ladder tied to career progression; and safeguards addressing ethics, data privacy, and equitable access. The analysis highlights enabling conditions (policy coherence, infrastructure, school leadership, and mentorship) and risks (inequity, deskilling, and overreliance on opaque systems). We conclude with an implementation roadmap for colleges of education, teacher training institutions, and regulators to mainstream AI literacy and practice, while protecting teacher agency and professional judgment.

Keywords: *Artificial intelligence; teacher education; professional standards; continuous professional development; career pathways; Nigeria*

Introduction

Artificial intelligence (AI) has moved from speculative technology to everyday infrastructure in education—supporting adaptive learning, automated feedback, analytics, and assistive tools. For Nigeria, the challenge is twofold: preparing teachers to use AI responsibly to improve learning and preparing future teachers whose professional identity, competencies, and career trajectories adapt to AI-mediated classrooms. Recent national policies and global frameworks provide guidance, while emerging Nigerian evidence shows potential gains in learning outcomes with AI-enabled tutoring. This paper synthesizes these developments and offers a practical roadmap for teacher education and career development in Nigeria.

Purpose and contribution. We integrate (a) Nigeria's latest AI policy directions; (b) UNESCO's AI competency frameworks for teachers; (c) TRCN professional and leadership standards; and (d) recent empirical evidence from Nigeria and comparable contexts. We then translate this synthesis into implementable recommendations for ITE, CPD, and career progression.

Policy and System Context in Nigeria

National strategies and regulation. Nigeria's National AI Strategy (2024) identifies education and skills as priority domains and calls for capacity strengthening for teachers and learners. The

Teachers Registration Council of Nigeria (TRCN) regulates teacher professionalism and publishes professional standards (2019) and leadership standards (2024). The National Policy on Education (6th ed., 2013) and National Commission for Colleges of Education (NCCE) Minimum Standards define the baseline for ITE programs, accreditation, and quality assurance.

Infrastructure and skills readiness. National diagnostics emphasize uneven digital infrastructure and gaps in foundational and advanced digital skills, which are prerequisites for effective AI use in schools. Addressing these gaps is critical to avoid widening inequities between urban and rural schools and between well-resourced and under-resourced teacher training institutions.

Literature Review

Global frameworks and principles. UNESCO’s AI Competency Framework for Teachers (2024/2025) identifies five dimensions—human-centred mindset, AI ethics, AI foundations and applications, AI pedagogy, and AI for professional learning—offering a reference for course design, practicum, and assessment in teacher education.

Empirical evidence from Nigeria. A 2025 randomized controlled trial (RCT) in Nigerian secondary schools evaluated AI-powered virtual tutoring using large language models and found significant learning gains, indicating that well-designed AI interventions can complement teachers and improve outcomes. Additional studies in Nigerian higher education report growing but uneven adoption of AI tools, with concerns about data privacy, academic integrity, and job reconfiguration among administrative roles. Recent work has also begun to quantify teachers’ readiness for AI adoption in Nigerian contexts, emphasizing the need for targeted professional learning.

Risks and ethical concerns. The literature flags risks such as amplification of bias in datasets, over-automation of assessment, privacy and data protection gaps, and potential deskilling if AI displaces, rather than augments, teacher judgment. These concerns underscore the need for teacher-centred, rights-preserving design and robust institutional governance.

Conceptual Framework

We adapt the TPACK (Technological Pedagogical Content Knowledge) model to the age of AI and pair it with UNESCO’s AI teacher competencies to create a **Nigerian AI-TPACK** view:

- **AI-TCK (AI–Technological Content Knowledge):** Teachers understand AI applications relevant to subject content (e.g., adaptive problem sets in mathematics; NLP-assisted writing feedback in English).
- **AI-TPK (AI–Technological Pedagogical Knowledge):** Teachers plan lessons that leverage AI responsibly (e.g., formative feedback via AI while maintaining human-graded summative assessments).
- **AI-PCK (Pedagogical Content Knowledge in AI contexts):** Teachers anticipate misconceptions AI tools may introduce and design activities that develop critical AI literacy.
- **Ethics and agency layer:** Explicit attention to fairness, transparency, and teacher decision-making authority.

Method: Targeted Scoping Review and Policy Analysis

We conducted a targeted scoping review of English-language sources from 2019–2025 focusing on (a) Nigeria’s AI and teacher education policies; (b) empirical studies of AI in Nigerian education; and (c) global AI teacher competency frameworks. Sources were identified via institutional repositories (TRCN, NCCE, Federal Ministry of Education), multilateral organizations (UNESCO, World Bank), and peer-reviewed outlets. We prioritized documents with clear methodological descriptions and Nigeria-specific evidence.

Findings and Analysis

Mapping UNESCO AI competencies to TRCN standards. Table 1 (below) aligns UNESCO’s five competency dimensions to TRCN’s Professional Standards domains (professional knowledge, skills, values/ethics), identifying course and practicum implications for ITE.

Table 1. Alignment of AI Teacher Competencies and TRCN Standards (illustrative)

UNESCO competency dimension	AI Closest standard domain	TRCN ITE implications	CPD implications
Human-centred mindset	Professional values & ethics	Embed reflective seminars on AI’s societal impacts; case studies on inclusion	School-based ethics rounds; policy literacy
Ethics of AI	Professional values & ethics	Modules on data protection, bias, and accountability	Annual refresher micro-credential; audit of classroom AI tools
AI foundations & applications	Professional knowledge	Intro to ML concepts; prompt design; data literacy	Tool-agnostic workshops; sandboxing
AI pedagogy	Professional skills	Lesson design with AI supports; formative assessment	Coaching cycles; communities of practice
AI for professional learning	Professional development	E-portfolios; peer observation with AI-assisted analytics	Micro-credentials linked to progression

What works: Evidence from Nigerian pilots. The 2025 RCT on AI tutoring demonstrates that generative AI, when aligned to curricula and supported by teacher facilitation, can improve learning. Similar pilots in higher education report efficiency gains in feedback and preparation, but also highlight the need for institutional guidelines.

Enabling conditions. Successful integration requires: (i) policy coherence between NAIS (2024), TRCN standards, and NCCE Minimum Standards; (ii) infrastructure (connectivity, devices, power); (iii) school leadership capacity to steward change; and (iv) professional learning ecosystems (mentors, peer networks, and CPD financing).

Risks and mitigations. To prevent inequity, prioritize underserved schools in infrastructure rollouts; to protect privacy, adopt data governance policies and procurement checklists; to safeguard professionalism, maintain teacher agency over assessment and grading; and to build trust, ensure transparent model documentation and bias audits for any classroom AI tool.

Implications for Teacher Education (ITE)

1. **Curriculum redesign:** Introduce a required, credit-bearing course on AI literacy and pedagogy in all Colleges of Education and Faculties of Education; integrate AI practice tasks within methods courses (e.g., AI-assisted lesson planning critiqued by peers and mentors).
2. **School-based practicum with AI:** Require at least one teaching practicum cycle where candidates plan, implement, and reflect on an AI-supported lesson, with attention to equity and ethics.
3. **Assessment:** Use human-moderated, AI-assisted formative assessment while retaining human-graded summative tasks; require e-portfolios evidencing competency across the five UNESCO dimensions.
4. **Quality assurance:** Update NCCE accreditation instruments to check for AI literacy, data protection protocols, and mentor capacity.

CPD and Career Development Pathways

We propose a **CPD micro-credential ladder** aligned to TRCN standards and tied to progression and incentives:

- **Level 1: AI Literacy (Foundations).** Core micro-credentials on ethics, privacy, prompt design, and classroom use cases.
- **Level 2: AI Pedagogy Specialist.** Subject-specific micro-credentials (e.g., AI for mathematics problem-solving; literacy and language arts).
- **Level 3: AI Coach/Mentor.** Coaching skills, implementation science, and evaluation methods; supports school-based professional learning communities.
- **Level 4: AI Lead/Coordinator.** School or district leadership on tool selection, procurement, data governance, and professional learning strategy.

Career progression and incentives should recognize micro-credentials (allowances, promotion points), with TRCN maintaining a national registry and quality assurance.

Implementation Roadmap (12–24 months)

- **Policy alignment:** Issue joint circulars aligning NAIS (2024), TRCN standards, and NCCE standards for Colleges of Education and universities.
- **Pilots and evidence:** Scale AI tutoring pilots in junior secondary with rigorous monitoring; prioritize states with existing connectivity programs.
- **Capacity building:** Train school leaders first; build a cadre of AI Coaches via short courses; integrate AI modules into existing CPD platforms.
- **Infrastructure & safety:** Procure devices with privacy-preserving defaults; adopt data-processing agreements; publish a national AI in Education procurement checklist.
- **Equity focus:** Target rural and underserved schools; provide offline-capable tools and power solutions; monitor gender and location gaps in access and outcomes.

Conclusion

AI presents a catalytic opportunity to upgrade teacher education and professional careers in Nigeria—provided that integration is teacher-centred, ethically grounded, and systemically supported. With clear competencies, aligned standards, robust CPD ladders, and attention to equity and governance, Nigeria can harness AI to enhance teacher professionalism and learning outcomes rather than diminish them.

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EFFECTS OF BLENDED LEARNING AND ARTIFICIAL INTELLIGENCE ON ACADEMIC ACHIEVEMENT AMONG BIOLOGY STUDENTS IN MINNA METROPOLIS NIGER STATE

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Abstract

The study investigated the effects of blended learning and artificial intelligence on academic achievement among biology students in Minna Metropolis Niger State. The research was guided by two objectives, research questions and hypotheses. Quasi experimental design was adopted for this research. Purposeful sampling technique was used to get the sample for the research. The research instruments were blended learning package, A.I. package and Biology Achievement Test (BAT). Three experts validated the instruments and reliability of the BAT was determined using Richard Kuderson which yielded 0.87. The data collected were analysed using mean and standard deviation to answer research questions and t-test to test the null hypotheses. From the result, A. I. has higher mean gain of 53.31 and standard deviation of 2.34 while the blended learning group had mean gain of 24.89 with standard deviation of 3.73. This indicates that both groups benefited from the treatment, but A. I group has the higher mean gain compared to blended learning strategy. The result showed that there was significant difference in academic achievement of students taught biology using blended learning and those taught using A.I. software. The analysis revealed that both blended learning and A.I software are not gender sensitive. The researcher recommended among others, that blended learning and A.I package be adopted for teaching biology in secondary schools in Minna Metropolis, Niger State

Keywords: *Blended learning, A.I, Biology Achievement*

Introduction

Biology is the scientific study of life and living organisms. It encompasses a wide range of sub-disciplines that explore the structure, function, growth, evolution, distribution, and taxonomy of living organisms. As a natural science, biology seeks to understand the fundamental processes that govern life, from the molecular level to entire ecosystems. Biology focuses on all aspects of living organisms, including their physical structure, chemical processes, molecular interactions, physiological mechanisms, development, and evolution. Biological study spans various levels of organization, from molecules and cells to organisms, populations, communities, and ecosystems. Biology explores the vast diversity of life forms, from single-celled microorganisms to complex multicellular organisms, including plants, animals, fungi, and protists. A central theme in biology is evolution, which explains the diversity of life and the adaptation of organisms to their environments through natural selection and genetic variation. Biological systems are highly interconnected, with each level of organization influencing and being influenced by others. This interconnectedness is crucial for maintaining homeostasis and overall function.

Understanding biology is essential for addressing public health issues. This includes studying the spread of diseases, understanding epidemiology, and developing vaccines. Public health initiatives rely heavily on biological research to prevent and control health crises. Biological literacy is important for fostering an informed and scientifically literate society. Knowledge of biology empowers individuals to make informed decisions about health, nutrition, and environmental issues. Biology raises important ethical and philosophical questions about life, consciousness, and the relationship between humans and other living organisms. This fosters critical thinking and informed discussions about bioethics, conservation, and the impact of scientific advancements. Biology is integral to numerous aspects of human life, from health and medicine to environmental sustainability and ethical considerations. Its contributions are essential for the well-being and progress of humanity in the world of information communication and Technology.

Information Communication and Technology (ICT) in education refers to the use of technology to support, enhance, and optimize the delivery of information and learning processes. This integration of technology in education encompasses a variety of tools and resources that improve teaching, learning, and administrative functions. The following are Digital Learning Resources: E-books and E-journals: Digital formats of books and journals provide easy access to a wide range of learning materials. Online Courses and MOOCs: Platforms like Coursera, edX, and Khan Academy offer courses on various subjects, often free of charge. Multimedia Content: Videos, animations, and simulations can make complex concepts easier to understand. Other modes of delivery of information are blended learning and artificial intelligence

Blended learning is an educational approach that combines traditional face-to-face classroom methods with online and digital learning activities. This hybrid model leverages the strengths of both in-person and virtual instruction to create a more flexible and personalized learning experience. Here are some key aspects of blended learning:

Components of blended learning include Face-to-Face Instruction: Traditional classroom teaching where students and instructors interact in person. Allows for direct engagement, real-time feedback, and hands-on activities. Online Learning: Utilizes digital platforms to deliver instructional content, assignments, and assessments. Can include video lectures, discussion forums, interactive simulations, and other web-based resources.

Benefits of Blended Learning include Flexibility: Offers students greater control over the time, place, and pace of their learning. Accommodates diverse learning preferences and schedules. Personalization: Enables differentiated instruction and tailored learning experiences. Allows educators to use data and analytics to monitor progress and adjust instruction accordingly. Engagement: Uses multimedia and interactive tools to create a more engaging and stimulating learning environment. Encourages active learning and participation. Access to Resources: Provides access to a wealth of online resources and materials. Facilitates collaboration and communication through digital platforms such as Artificial Intelligent

In the bustling corridors of modern education, a silent revolution is underway, one driven not by the chalk dust of yesteryears, but by the ethereal hum of algorithms and data. Artificial Intelligence (AI), once a futuristic concept confined to the realms of science fiction, now stands as a formidable force shaping the landscape of education. Zhai (2023) Its influence permeates classrooms, lecture

halls, and virtual learning environments, promising a paradigm shift in the way we teach and learn. At its core, AI in education is not merely about replacing teachers with machines or inundating students with digital resources. It's about augmenting human potential, empowering educators, and personalizing learning experiences to unprecedented levels. Imagine a classroom where every student's strength, weaknesses, and learning styles are not just recognized but catered to with surgical precision. This is the promise of AI in education a promise that is already beginning to unfold without gender biased.

Gender has been described as a cultural construct and social positions which members of the society have attached to the descriptions of either being male or female. Gender also means a dimension of social organization which shapes how people interact with one another and how people behave or act and think about themselves. It also includes hierarchy and ranking of men and women distinctly in terms of power, wealth, privilege and other resources. Akinwumi and Falemu (2020) stated that gender is a social or cultural determinant that varies from place to place or culture to culture. It is not universal, unlike sex which is biologically determined and universal. Abiodun (2014), observed that throughout life (birth and death), human feelings, thought and actions reflect the social definitions that people attach to gender which influence the way individuals, and their daily activities may either be positively or negatively impacted. As gender affects the way people think of themselves, it teaches them to act in normative ways, that is acting and feeling in the manner that the society ascribed to each sex. Abakpa et al., (2016), maintained that as much as culture defines males as ambitious and competitive and females as conservatives the discrimination begins from the family and is later extended to other areas of one's life where a man sees himself as superior in every human endeavour and sees woman as differential and emotional. Males are expected to aspire to leadership positions while females are expected to be good listeners and supportive observers.

Achievement is seen as the act of accomplishment of a task. It is something accomplished successful, especially by means of exertion, skills, practice or perseverance (Garrett, *et all* 2021). Achievement is measured by students' performance after receiving lessons on a given subject or topics. It is measured through a test that is based on a given standard. To (Pawel, *et all* 2022) academic achievement is excellence in all academic disciplines in the class as well as extracurricular activities. Academic achievement could be associated with how students deal with their studies, and how they cope with or accomplish different tasks given to them by a teacher.

Statement of Problem

The integration of technology into education has revolutionized the way teaching and learning occur. Some of such innovations are blended learning and artificial intelligent (A.I), which combines traditional face-to-face instruction with online educational materials and activities. Despite its growing popularity, there remains a gap in understanding the specific impact of blended learning and artificial intelligent software on student achievement particularly in the context of biology education within Minna Metropolis, Niger State.

Biology, being a core science subject, is fundamental to students' understanding of the natural world and is critical for many future career paths in science, health, and technology. However, traditional methods of teaching biology have often been criticized for being overly didactic and failing to engage students actively, leading to poor achievement. This challenge is particularly

pronounced in Minna Metropolis, where educational resources and access to cutting-edge technology are limited.

Blended learning and artificial intelligent (A.I.) have the potential to address these challenges by providing interactive, flexible, and personalized learning experiences. Yet, there is limited empirical evidence on how blended learning and artificial intelligent software specifically affects the achievement of biology students in Minna metropolis. Therefore, this study seeks to investigate the effects of blended learning and A.I. software on the achievement of biology students in Minna Metropolis, Niger State

Aim and Objectives of the study

The work aimed at investigating the effects of blended learning and A. I. software on the academic achievement of biology students in Minna Metropolis, Niger State

The following specific objectives are to be achieved

- i. Determine the effect of blended learning and A.I on academic achievement of Biology students in Minna Metropolis
- ii. Determine the influence of gender on the academic achievement of Biology students in Minna Metropolis

Research Questions

1. What is the mean difference between student taught using blended learning and those taught using A.I
2. What is the mean difference between academic achievement of biology students taught using blended learning based on gender
3. What is the mean difference between biology students taught biology using A. I. based on gender

Research Hypotheses

HO₁: There is no significant difference in the academic achievement of Biology students taught biology using blended learning and those taught using A.I.

HO₂: There is no significant difference in mean academic achievement of male and female students taught biology using blended learning

HO₃: There is no significant difference in the academic achievement of male and female students taught biology using A.I.

Methodology

The research design adopted for this study was quasi-experimental design. Non-equivalent, non-randomized research design. This design is suitable to determine the effects of blended learning and A.I on the academic achievement of student taught biology. The independent variables are blended learning and A.I, dependent variable is achievement, moderating variable is gender. It has the following research Layout:

Groups	Pre-test	Treatment	Post-test
Experimental 1	O ₁	X ₁	O ₃
Experimental 2	O ₂	X ₂	O ₄

O₁, O₂ = pre-test
O₃, O₄ = post-test
X₁, X₂ = treatment

Population of The Study

The target population for the study was 120 Biology students from across all 17 Senior Secondary Schools with total population of 4,182 in Minna metropolis, Niger State

Sample and Sampling Techniques

Purposive sampling technique was used to sample two secondary school with ICT facilities and availability of internet was also considered and random sampling was used to sample class to be used for the experiment

Research Instrument

The research instrument for this research is, blended learning package, A.I. package and Biology achievement Test (BAT).

Validation of the Instrument

Face validity of the instrument was established by three experts in Biology from the Department of Science Education and Department of Educational Technology, Federal University of Technology Minna, Niger State. Each of the experts was served with a copy of the instrument and requested to watch the A.I and Blended learning Packages with Biology Achievement Test, identify ambiguities and proffer solutions for improving the instrument. This was to assess the appropriateness of the instrument in terms of sentence structure, relevance of the subject matter and the effectiveness of the instrument to measure exactly what it is supposed to measure. Their observations and comments were used to improve the content of the instrument for the final production

Reliability of the Instrument

Pilot study was conducted on twenty-five senior secondary school biology students from Bahago Secondary School Minna which is part of population but not sampled for this research. The data generated from this pilot study was analysed using Kuder Richardson which yielded 0.87 which is reliable for this research

Method of Data Collection

The researcher administered the BAT as the pretest to the entry behaviour of the students that are participating in the research. After this, these biology students in experimental group 1 were exposed to A.I software that has genetics as its content and those in experimental group 2 was exposed to blended learning software that contain genetics as its content after they have all received the treatment for four weeks BAT was administered as post-test.

Method of Data Analysis

The data collected was analysed using simple descriptive statistics and inferential statistics. The research questions were answered using mean and standard deviation. Inferential statistical independent t-test was used to test the hypotheses. The hypotheses were tested at 0.05 level of significance with the use of Statistical Package for Social Sciences (SPSS) Version 23.

Results and Discussions

Research Question One:

What is the mean difference between student taught using blended learning and those taught using A.I?
Table 1 shows the mean difference between the biology students using A. I. and Biology students taught using blended learning strategy

Table 1: Mean and Standard Deviation of students Taught Using AI and Those Taught Using Blended Learning Strategy

Groups	Pretest scores	Pretest Standard deviation	Post-test mean	Post-test Standard Deviation	Post-test mean Gain	Difference in Standard Deviation
AI	12.82	9.79	66.13	12.13	53.31	2.34
Blended Learning	14.34	9.53	39.23	13.26	24.89	3.73

From table 1, it was observed that both groups had improvement as observed in their post-test for example, A. I. has higher mean gain of 53.31 and standard deviation of 2.34 while the blended learning group had mean gain of 24.89 with standard deviation of 3.73. This indicates that both groups benefited from the treatment, but A. I group has the higher mean gain compared to blended learning strategy.

Research Question Two:

What is the mean difference between male and female biology student taught using blended learning?

Table 2: Mean and Standard Deviation of Male and Female Students Taught Biology Using Blended Learning

Groups	Pretest Mean scores	Pretest Standard deviation	Post-test mean	Post-test Standard Deviation	Post-test mean Gain	Difference in Standard Deviation
Male	12.06	8.99	65.16	10.32	53.10	1.33
Female	14.21	10.78	66.83	14.13	52.62	3.35

From table 2, it was observed that both male and female had improvement as observed in their post-test, for example male has higher main gain of 53.10 and standard deviation of 1.33 while the female had mean gain of 52.62 with standard deviation of 3.35. This indicates that both male and female benefited from the treatment, but male group has the higher mean gain compared to female

Research Question Three: What is mean difference between academic achievement of biology students taught using AI based on gender?

Table 3 show the difference in the mean difference of male and female Biology students taught using AI

Table 3: Mean and Standard Deviation of Male and Female Biology students Taught Using AI

Groups	Pretest Mean scores	Pretest Standard deviation	Post-test mean	Post-test Standard Deviation	Post-test mean Gain	Difference in Standard Deviation
Male	14.33	9.79	51.13	18.72	36.60	8.93
Female	12.95	9.67	54.30	18.21	41.35	5.26

From table 3, it was observed that both groups had improvement as observed in their post-test for example female has higher main gain of 41.35 and standard deviation of 5.26 while the male had mean gain of 36.60 with standard deviation of 8.93. This indicates that both groups benefited from the treatment, but female group has the higher mean gain compared to male.

Hypotheses testing

HO₁: There is no significant difference in the academic achievement of Biology students taught biology using blended learning and those taught using A.I. Table 4 shows the t-test of biology study using A.I. and blended learning

Table 4: t-test of Biology Students taught using AI and Blended Learning Strategies

Variables	N	X	SD	Df	t-value	P	Remark
AI	60	66.13	12.13	118	11.535	0.000	Significant
Blended learning	60	39.20	13.26				

Table 4 presents the t-test of AI. and Blended groups. The mean scores of AI. was 66.13 and 39.20 for Blended learning group. The t-value is 11.535 was significant at 0.05 level. Hence the null hypothesis one (HO₁) was rejected with a mean difference of 26.93 in favour of AI group.

HO₂: There is no significant difference in mean academic achievement of male and female students taught biology using blended learning.

Table 5 presents t-test analysis of male and female Biology students taught using blended learning

Table 5: Analysis of t-test of male and female Biology students taught using Blended learning

Variables	N	X	SD	Df	t-value	P	Remark
Male	28	19.23	9.70	58	0.675	0.836	Ns
Female	32	19.95	9.67				

Table 5 shows the achievement of male and female biology student taught using Blended learning. The table shows that t-value = 0.675 and p-value = 0.836 > 0.05. Therefore, the null hypothesis is accepted, consequently, it is concluded that there is no significant difference in achievement of male and female biology students taught biology using Blended learning.

HO₃: There is no significant difference in achievement of Biology student taught using AI
Table 6 presents the t-test of male and female Biology Students taught using AI

Table 6: t-test analysis of male and female Biology students taught using AI.

Variables	N	X	SD	Df	t-value	P	Remark
Male	28	14.33	9.70	58	0,78	0.436	Ns
Female	32	12.95	9.67				

Table 6 shows the achievement of male and female biology student taught using A. I. The table shows that t-value = 0.78 and p-value = 0.436 > 0.05. Therefore, the null hypothesis is accepted, consequently, it is concluded that there is no significant difference in achievement of male and female biology students taught biology using AI.

Discussion of Findings on Achievement

From table 1 it was discovered that there was significant difference between the biology students taught using A. I. and blended learning, with A. I. group having the higher mean and standard deviation which means A. I. group benefited from the treatment than blended learning group. This finding concurred with the findings of Taliat (2025) who works on A.I enhanced skill development: leveraging A.I in Biology education to develop skills in digital era and finally found out that A.I improve Biology student achievement. This finding also agreed with findings of Quasirr *et al* (2024) who found that blended learning also improve the achievement of Biology students taught using blended learning

Findings on Gender Using Blended Learning and AI. Learning Software

Table 5 and 6 show that both A.I blended learning software are gender friendly, since both male and female benefited maximally from blended learning and A. I. learning software. This finding agreed with the findings of Salaudeen *et al* (2017) who says gender does not affect achievement of biology students using podcast.

Conclusions

Because of this, secondary schools must push for the development of more online and offline learning tools to help students learn. Mobile devices are quickly taking the place of standard classroom tools as the main way that students communicate and work together. Teachers should always be on the lookout for fresh, useful ways to help their students make the most of these chances. So, teaching methods created for A. I and blended-level classrooms are good for students' well-being, school progress, focus, and desire to study.

Recommendations

the following recommendations were proffered by the researcher.

1. Teachers to embrace Blended Learning to combine digital tools with classroom interaction, increasing flexibility and student engagement.
2. Teachers to integrate AI Tools to provide personalized learning paths and instant feedback, helping to address individual student needs.
3. Government to provide Teacher Training on both blended learning models and AI platforms to build confidence and effective usage.

4. Government to start with Pilot Programmes to demonstrate success and refine strategies before school-wide implementation.
5. Government to develop Clear Guidelines for the ethical use of AI to ensure academic integrity and data privacy.
6. All the stakeholder to Foster a Future-Ready Culture where technology enhances critical thinking and prepares students for a digital world.

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COMPARATIVE EFFECTS OF ROSETTA STONE AND BUSUU LANGUAGE LEARNING APPLICATIONS ON SECONDARY SCHOOL STUDENTS' VOCABULARY LEARNING OUTCOMES

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Abstract

The increasing adoption of Artificial Intelligence (AI)-powered language learning applications has transformed vocabulary teaching and learning across educational levels. Among these, Rosetta Stone and Busuu stand out as two globally popular platforms offering adaptive, multimedia-based and communicative learning experiences. Despite their success in adult and autonomous learning contexts, the question remains whether these tools can effectively enhance vocabulary learning outcomes among secondary-school students, particularly in formal classroom settings. This opinion paper critically examines the comparative potential of Rosetta Stone and Busuu for improving vocabulary learning in secondary education. Drawing upon recent research and theoretical perspectives on digital and mobile-assisted language learning, the paper discusses their pedagogical affordances, challenges, and implications for curriculum integration. It argues that both platforms can significantly enrich vocabulary instruction when contextualised within blended or guided learning frameworks. However, the effectiveness of each depends on learner age, motivation, and teacher mediation. The paper concludes with recommendations for policymakers, teachers, and researchers on optimising the educational use of these platforms in vocabulary development.

Keywords: *Rosetta Stone, Busuu, vocabulary learning, mobile-assisted language learning, AI in education, secondary school*

Introduction

Language learning has undergone a profound transformation in the digital era, with mobile-assisted and AI-powered tools reshaping traditional pedagogical boundaries. Vocabulary, a foundational element of communicative competence, has particularly benefited from these innovations. Applications such as Rosetta Stone and Busuu have been widely used by learners to enhance their vocabulary knowledge through interactive, multimedia, and self-paced experiences (Seals, 2024; Duan, 2024). Yet, in secondary-school contexts where learners are still developing metacognitive regulation and self-direction the use of such applications raises critical pedagogical questions.

This paper presents an informed perspective on the comparative effectiveness of Rosetta Stone and Busuu in enhancing vocabulary learning outcomes among secondary-school students. It explores how these platforms align with current theories of language acquisition, their technological affordances, pedagogical implications, and contextual limitations. The goal is not to

report empirical findings but to offer a theoretically grounded commentary that can guide future research and educational practice.

The Changing Landscape of Vocabulary Learning

Vocabulary learning is no longer confined to rote memorisation or textbook exercises. The integration of digital tools has introduced new modalities visual, auditory, and interactive that foster deeper processing and engagement. According to Chuane (2025), technology-mediated learning environments, when guided by the Community of Inquiry (CoI) framework, can significantly enhance both vocabulary knowledge and motivation by combining cognitive, social, and teaching presence.

Similarly, Kafabih (2021) noted that mobile applications encourage authentic language exposure and learner autonomy, which are essential for meaningful vocabulary acquisition. These applications often incorporate gamification, adaptive feedback, and spaced repetition algorithms techniques that have been shown to support long-term retention (Karacan & Akoglu, 2021; Cerezo & Pujolà, 2025).

The current generation of learners often referred to as *digital natives* interact naturally with these platforms. Yet, secondary-school classrooms face challenges such as unequal access to devices, limited teacher training, and misalignment between digital resources and curriculum objectives. Within this context, understanding how tools like Rosetta Stone and Busuu can complement formal teaching is crucial.

Rosetta Stone: Immersive Learning through Structured Repetition

Rosetta Stone is one of the earliest and most established digital language-learning applications. It adopts a “Dynamic Immersion” approach that mirrors first-language acquisition, presenting learners with contextualised images, audio, and written prompts without direct translation. This method encourages learners to infer meaning and develop vocabulary through repeated exposure to authentic input.

Munthe (2020) demonstrated that Rosetta Stone significantly improved Indonesian students’ vocabulary mastery at the secondary level, mainly due to its multimodal design and immediate feedback mechanisms. The application’s speech recognition system also supports pronunciation accuracy, fostering phonological awareness alongside lexical learning (Vančová, 2023).

Rosetta Stone’s structured sequence of lessons promotes gradual vocabulary building and integration across listening, reading, and speaking modes. However, one limitation is its relatively linear design, which may not fully engage learners who prefer social interaction or collaborative learning. Moreover, the app’s commercial orientation and subscription model could restrict accessibility in public schools within developing contexts.

Nevertheless, Rosetta Stone's controlled learning environment makes it suitable for classroom use under teacher supervision. Teachers can select relevant modules aligned with curriculum themes and monitor progress through built-in dashboards.

Busuu: Social Learning and Adaptive Feedback

Busuu, in contrast, represents a more socially oriented platform that integrates human interaction with AI-based personalisation. It combines structured lessons with opportunities to communicate with native speakers and other learners worldwide. Its integration of community-based practice aligns with socio-constructivist principles, where knowledge is co-created through dialogue and social feedback (Rajan *et al.*, 2025).

Recent studies show that Busuu fosters vocabulary retention through micro-learning, contextual dialogues, and spaced repetition algorithms (Nouria & Fatima, 2024). Its built-in adaptive review system tailors vocabulary revision to each learner's performance, offering a more flexible and personalised experience than Rosetta Stone.

From a pedagogical standpoint, Busuu supports learner motivation by providing badges, progress tracking, and peer corrections—elements of digital ludic pedagogy that sustain engagement (Cerezo & Pujolà, 2025). It encourages learners to use new vocabulary in communicative contexts, bridging the gap between controlled practice and authentic language use.

However, Busuu's open social features may pose moderation challenges in classroom environments, and its reliance on consistent internet connectivity can hinder equitable access. In addition, unsupervised use may lead to distractions or superficial engagement with vocabulary items.

Theoretical Perspectives

The comparative analysis of these two platforms can be situated within several theoretical frameworks:

Constructivism and CoI Framework

Constructivist theory posits that learners construct meaning actively through interaction with their environment. Rosetta Stone's immersive approach corresponds with cognitive constructivism, where learners internalise vocabulary through meaningful association. Busuu, conversely, reflects social constructivism by promoting learning through collaboration and peer feedback (Chuane, 2025).

The Community of Inquiry (CoI) model further explains how digital learning environments can integrate cognitive, social, and teaching presence. Rosetta Stone strengthens cognitive presence through structured input and self-assessment, while Busuu enhances social presence through global learner interaction. For secondary-school contexts, the role of teaching presence teacher guidance and scaffolding is essential to balance autonomy with structure.

Dual-Coding and Multimodal Learning

Both platforms leverage the dual-coding principle, which posits that combining verbal and visual input enhances memory retention. Rosetta Stone's image-based cues support conceptual mapping of vocabulary, while Busuu's contextual dialogues provide multimodal reinforcement. As Karacan and Akoglu (2021) argue, multimodal learning environments promote deeper vocabulary processing by stimulating multiple sensory pathways.

Motivation and Self-Determination Theory

Motivation remains a decisive factor in vocabulary acquisition. Busuu's gamified design and social connectivity promote intrinsic motivation through relatedness and competence, whereas Rosetta Stone's structured progression appeals to extrinsically motivated learners who value measurable progress. According to Duan (2024), motivation is central to the success of mobile-assisted language learning, as engagement sustains consistent exposure necessary for vocabulary retention.

Comparative Effects on Achievement, Retention, and Interest

Vocabulary learning outcomes are multidimensional. In educational research, three interrelated variables achievement, retention, and interest serve as indicators of effective learning. Achievement reflects immediate vocabulary acquisition, retention represents long-term memory of learned words, and interest refers to the learners' sustained motivation and affective engagement.

Achievement

Achievement in vocabulary learning is often measured by students' ability to recognise, recall, and use new words accurately. Both Rosetta Stone and Busuu have demonstrated potential to enhance this cognitive dimension through different mechanisms.

Rosetta Stone supports achievement through its **structured immersion model**, which provides consistent exposure, repetition, and context-based reinforcement. Munthe (2020) reported a significant improvement in secondary-school learners' vocabulary scores after sustained use of Rosetta Stone, attributing the gains to the multimodal design and immediate feedback. Its lesson sequencing follows the principle of *cumulative mastery*, ensuring that new vocabulary builds upon previously learned material.

Busuu, on the other hand, drives achievement through **social practice and adaptive feedback**. Nouria and Fatima (2024) noted that AI-based feedback within Busuu enhances learners' awareness of errors and reinforces correct lexical usage. The platform's community features encourage students to apply vocabulary in authentic exchanges, deepening understanding and functional competence. Chuane (2025) added that the presence of peer interaction creates a socially supportive learning environment that contributes positively to achievement in vocabulary learning.

Comparatively, while Rosetta Stone's achievement effect may manifest more strongly in controlled and structured learning environments, Busuu's achievement gains often depend on the learner's level of engagement and the teacher's capacity to scaffold online interactions.

Retention

Retention the ability to recall and reuse vocabulary after the learning period remains a crucial measure of meaningful learning. Theories of memory consolidation emphasise spaced repetition, multimodal association, and contextual use as core mechanisms for long-term retention.

Rosetta Stone promotes retention through repeated exposure to visual and auditory cues that reinforce memory traces. Its use of implicit learning and constant recycling of learned items ensures that vocabulary is revisited across different linguistic contexts, facilitating durable retention (Seals, 2024).

Busuu enhances retention through **adaptive review algorithms**, which automatically schedule vocabulary revision based on learner performance. This aligns with Duan's (2024) findings that mobile-assisted platforms incorporating spaced repetition significantly improve learners' long-term recall of foreign-language vocabulary. Busuu's microlearning format—short, frequent lessons—also fits secondary students' attention span, maintaining cognitive engagement without overload.

Importantly, retention is strengthened when teachers integrate reflective activities such as quizzes, games, and storytelling that reactivate words learned on these apps. Without such reinforcement, vocabulary may remain inert, reducing the long-term effectiveness of digital learning.

Interest

Interest plays an indispensable role in sustaining vocabulary learning. In the context of mobile-assisted learning, **interest is both an antecedent and an outcome** of effective instructional design.

Busuu is particularly effective in stimulating interest due to its **gamified elements** badges, progress bars, and community recognition. Cerezo and Pujolà (2025) highlighted that ludic (play-based) elements in digital learning environments sustain motivation and positive affective engagement, especially among adolescents. The social networking features allow learners to feel part of a global community, enhancing their sense of purpose and enjoyment.

Rosetta Stone, although less interactive socially, maintains interest through **immersive audio-visual learning**. Students often report a sense of accomplishment from completing modules and mastering pronunciation with the AI speech recogniser (Vančová, 2023). However, for younger secondary-school learners, sustained interest may depend on the teacher's ability to contextualise app activities with classroom discussions and collaborative tasks.

According to Self-Determination Theory, interest flourishes when learners experience autonomy, competence, and relatedness. Busuu supports autonomy and relatedness through peer communication, whereas Rosetta Stone emphasises competence through structured mastery. Teachers can enhance interest further by allowing learners to set personal goals within each platform, thus creating a sense of ownership over learning.

Integrative Perspective

The interconnection between achievement, retention, and interest underscores the importance of **balanced instructional design**. Achievement provides the foundation for retention, while interest sustains engagement long enough for meaningful learning to occur.

In practice:

- **Rosetta Stone** maximises *achievement* and *retention* through structured exposure and feedback.
- **Busuu** maximises *interest* and *retention* through interactive and adaptive features.

An integrated approach using Rosetta Stone for foundational vocabulary building and Busuu for communicative reinforcement could yield optimal outcomes across all three variables. Such integration aligns with Chuane's (2025) CoI-based model, where cognitive presence (achievement), teaching presence (retention support), and social presence (interest) interact to produce holistic learning.

Comparative Analysis: Strengths and Limitations

Criteria	Rosetta Stone	Busuu
Pedagogical Approach	Structured immersion; cognitive focus	Social, communicative, and adaptive learning
Key Features	Speech recognition, image-based input, progression tracking	Peer interaction, adaptive review, gamification
Vocabulary Acquisition Style	Repetition and contextual deduction	Contextual communication and peer correction
Learner Engagement	Moderate; task-oriented	High; socially driven
Teacher Role	Facilitator and monitor	Guide and community moderator
Suitability for Secondary Students	Effective under guided use	Effective for motivated learners with digital access
Potential Drawbacks	Less collaborative; costly	Requires stable internet; possible distractions

While Rosetta Stone excels in structured delivery and pronunciation accuracy, Busuu provides richer opportunities for authentic vocabulary use. The choice between the two depends largely on the instructional context, learner maturity, and pedagogical objectives.

Implications for Teaching and Research

The inclusion of achievement, retention, and interest as focal variables has vital implications for teaching and research:

1. **Curriculum Design:** Vocabulary learning should move beyond rote memorisation towards engaging, multimodal, and interactive learning tasks that strengthen both short-term achievement and long-term retention.
2. **Assessment Practices:** Schools should include delayed post-tests to measure retention alongside immediate achievement tests.
3. **Motivational Scaffolding:** Teachers should adopt motivational strategies—goal setting, peer collaboration, and gamified rewards—to sustain interest, particularly during extended use of Rosetta Stone or Busuu.
4. **Blended Learning Models:** Combining the structured mastery of Rosetta Stone with the communicative, social engagement of Busuu can enhance achievement, retention, and interest simultaneously.
5. **Future Research:** Empirical studies should investigate causal links between these variables using pretest–posttest designs with delayed assessments. Qualitative studies could explore how learner emotions and preferences influence the effectiveness of each platform.

Pedagogical and Policy Implications

Curriculum Integration

Both Rosetta Stone and Busuu should not be treated as stand-alone learning tools but rather as complementary resources within blended learning frameworks. Teachers can use them for vocabulary enrichment activities, pronunciation practice, or differentiated instruction. The integration should align with curricular goals and assessment criteria to ensure continuity between digital and classroom learning.

Teacher Training and Support

Effective implementation demands that teachers acquire digital pedagogical competence. As Kouveli, Gazis, and Vavouras (2024) emphasised, teachers' attitudes and familiarity with multimedia tools significantly affect learners' engagement and outcomes. Professional development programmes should therefore include practical training on selecting, integrating, and evaluating language-learning apps.

Equity and Access

The digital divide remains a pressing issue. Schools must ensure equitable access to devices, stable internet connectivity, and licensed software. Policy initiatives should support partnerships with developers to provide subsidised educational licences for secondary institutions, especially in under-resourced regions.

Ethical and Data Privacy Considerations

AI-powered applications collect vast amounts of learner data. Calenda (2025) warned that data-driven personalisation, while beneficial, must adhere to strict privacy protocols to protect minors. Schools adopting Rosetta Stone or Busuu should implement data governance policies compliant with international standards.

Towards AI-Enhanced Vocabulary Learning

Emerging AI technologies present unprecedented opportunities for adaptive feedback and personalised vocabulary instruction. Heddadi (2025) found that university students using AI applications in Algeria experienced improved engagement and learning efficiency. Similarly, Vančová (2023) observed that AI-driven pronunciation correction fosters autonomous practice. For secondary schools, integrating such intelligent tutoring features within teacher-guided frameworks could revolutionise vocabulary pedagogy.

Challenges and Future Directions

Despite their potential, integrating Rosetta Stone and Busuu in secondary education faces several challenges:

1. **Cognitive Load:** Excessive multimedia stimuli can overwhelm younger learners.
2. **Motivational Sustainability:** Gamified engagement may decline over time without teacher reinforcement.
3. **Curriculum Misalignment:** Vocabulary taught in apps may not correspond with local syllabi.
4. **Teacher Resistance:** Limited digital literacy may impede adoption.
5. **Infrastructure Constraints:** Poor internet access and lack of devices remain barriers in many schools.

Future research should therefore examine *contextual adaptation*, focusing on how these platforms can be localised linguistically and culturally. Mixed-method studies exploring learner motivation, teacher attitudes, and long-term retention would deepen understanding of their efficacy in formal education.

Conclusion

In the evolving landscape of language education, digital applications such as Rosetta Stone and Busuu represent powerful tools for vocabulary development. This paper has argued that both possess distinct pedagogical advantages: Rosetta Stone excels in structured, immersive vocabulary acquisition, while Busuu thrives on social interaction and adaptive feedback. However, their full potential can only be realised when integrated within coherent pedagogical frameworks that combine technology with teacher mediation.

For secondary-school students, vocabulary learning is not merely about memorising words but about developing communicative competence and confidence. Both Rosetta Stone and Busuu, if effectively implemented, can serve as catalysts for such holistic growth. The challenge for

educators and policymakers is to create equitable, well-supported environments where digital language learning complements traditional methods rather than competes with them.

Recommendations

1. **Blended Implementation:** Integrate Rosetta Stone and Busuu as supplementary tools within structured lesson plans rather than stand-alone activities.
2. **Teacher Mediation:** Provide teachers with training to guide students' digital learning and monitor progress.
3. **Curriculum Alignment:** Select vocabulary themes that match local syllabi and communicative needs.
4. **Equity and Access:** Ensure institutional support for devices, internet access, and affordable licensing.
5. **Future Research:** Conduct comparative experimental studies on vocabulary retention, motivation, and learner attitudes toward these tools.

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AWARENESS, UTILISATION AND PERCEPTION OF TECHNOLOGY INTEGRATION FOR SCIENCE INSTRUCTION AMONG TEACHERS AND STUDENTS IN LEARNING INSTITUTIONS: IMPLICATION FOR THE SMOOTH IMPLEMENTATION OF ARTIFICIAL INTELLIGENCE IN EDUCATION IN NIGERIA

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Abstract

Educational policy and practice in Nigeria increasingly emphasize technology integration in science instruction. Evidently, integration of technology is crucial to the clarion call by the modern technology to integrate Artificial intelligence in all aspects of life, including education. This underscores the need to studies factors that could serve as barriers to that effect. This position paper meta-analyzed the research results on awareness, perception, utilization and possible impediments to effective integration of technologies in to teaching of science in Nigeria. Empirical studies from states like FCT, Abuja, Ikot Ekpene, Ilorin, Nasarawa, Bauchi, Rivers State, and others were studied and synthesized. From the meta-analysis, it became evident that, structural and contextual barriers such as inadequate infrastructure, limited teacher training, and weak administrative support significantly impinge on utilisation of technologies in to teaching of science. The body of empirical research suggests that science teachers in Nigeria are aware of ICT tools and hold positive perceptions about their potential for improving instruction. However, utilisation lags behind due to resource deficiencies, skill gaps, and weak institutional support. Specifically, secondary school biology teachers in, are positioned to benefit from targeted interventions to close this gap. The paper recommended among others that Developing clear, enforceable policy mandates that embed technology integration in teacher evaluation and curriculum delivery is necessary. Also, government should ensure consistent funding for ICT infrastructure in both urban and rural schools, including reliable power, internet access, and hardware/software will go a long way in fostering smooth acceptance and integration of technologies in to teaching of science in learning institutions of Nigeria.

Keywords: *Technology integration; Awareness; Utilisation; Biology instruction; Secondary education; Nigeria*

Introduction

In recent years, global scholarship has underscored that technology integration in education enhances student engagement, comprehension of complex scientific concepts, and overall learning outcomes (Buabeng-Andoh, 2019). In Nigeria, science education policy proposes technology-enabled instruction, yet empirical studies show persistent mismatches: biology teachers often are aware of ICT tools but do not fully utilise them (Ekon *et al.*, 2025; Abidoye and Adeyemi, 2020). Awareness and perception are necessary precursors to technology use, but they are not sufficient. A study in Ikot Ekpene found urban biology teachers had more access and used ICT resources regularly, while rural teachers lacked both access and utilisation (Ekon *et al.*, 2025). Similarly, in

Ilorin, secondary school biology teachers exhibited positive perceptions of ICT use (Abidoye and Adeyemi, 2020), yet utilisation was constrained by limited infrastructure, power supply, and teacher training (Barde, 2017; Nwobodo and Udoka, 2025).

Biology instruction poses particular demands: the subject requires visualisation (microscopic, molecular), interactive modelling, and laboratory work that can be augmented by virtual or low-cost technologies (Omolafe *et al.*, 2022). These affordances make biology a key domain for investigating technology integration.

Statement of the problem

Despite the global crave for the integration of AI, the effective implementation remains unachieved. Several factors are thought to be responsible but there is limited meta-analysed reports showcasing those challenges at a glance. For example, In Nigeria, to be precise, Federal Capital Territory (FCT), Abuja, a cosmopolitan area with potentially greater access, studies on these issues remains inadequate or remains under documented. Thus, the need to report the general status of the perception, awareness, attitude, as well as the systemic impediments that prevent effective utilisation among learning institutions.

Aim and Objectives

The aim of this paper was to meta-analyse the evidence from secondary studies about levels of awareness, perception, and utilisation of technology among biology (and related science) teachers in Nigeria.

1. To analyze the level of awareness, perception, utilization of AI in learning institutions
2. To highlight structural and contextual barriers impeding utilisation of AI across the learning institutions.

Results

Secondary Data from Related Empirical Studies

To ground this position, I summarise findings from ten empirical studies relevant to the topic:

Study	Location	Key Findings Relevant to Awareness / Perception / Utilisation	Barriers Identified
Ekon, Udoh, Ntukidem, and Osu (2025) Ikot Ekpene, Akwa Ibom State	Urban and rural secondary schools	High awareness of ICT resources among urban biology teachers; utilisation is much lower, especially in rural areas.	Inadequate ICT resources, power outages, and a lack of training.
Abidoye and Adeyemi (2020), Ifelodun LGA, Kwara State	Secondary biology teachers	Teachers perceive ICT use as significant for biology instruction; awareness is high.	Gender and experience are not major differentiators; challenges include insufficient ICT infrastructure and a lack of in-service training.
Barde, Mohammed (2017) Bauchi State	Public secondary schools in Bauchi State	Readiness (skills, attitude) varies; external readiness (facilities, administrative support) is very low.	Poor resource allocation, low teacher competence, and weak administrative support.
Omolafe, Olumorin, Adetunji, and Omolafe (2022). Ilorin, Nigeria	Secondary students and biology classes	Low-cost technology has a positive effect on students' biology performance. Improvised technologies	Limited access to high-end ICT, teacher training deficits.

Study	Location	Key Findings Relevant to Awareness / Perception / Utilisation	Barriers Identified
		are used in teaching, but rarely robust, interactive ICT tools.	
Nwobodo and Udoka (2025) Rivers State	Public Senior Secondary Schools	Teachers have moderate to high ICT proficiency; however, actual integration into teaching is low.	Erratic power, poor internet, lack of technical support, and institutional barriers.
Akanbi Jimoh et al. (2025), Nigeria	Biology teachers in the North-Central states	Academic qualification predicts ICT skill level and influences pedagogical approaches. High qualifications correlate with higher utilisation.	Disparity in teacher qualification; unequal access to professional development.
Buabeng-Andoh (2019), Ghana	Secondary schools, public/private in Ghana	Use of ICT is mainly for basic tasks (presentations, searches); advanced/integrated uses are limited. Teachers' attitudes are positive, but not deep.	Skill deficits, lack of confidence, and limited resources.
Usman, Obisesan and Ifabiyi (2025). Teacher Education Colleges in Kwara State	Teacher educators	Integration in teacher training is improving but hampered by resource constraints, resistance to change. Awareness is high among teacher educators.	Budget, infrastructure in teacher training colleges, and slow adaptation of curricula.
Ibrahim, Surajo, and Aliyu (2023) NCE Students, Zaria	Pre-service biology education students	Students' perceptions of web-based instruction are positive; awareness of AI-integrated and digital tools is growing.	Limited practical exposure; gap between curricula aspirations and available instructional materials.
Instructional Methods and Generative AI Integration among Biology Teachers in Ilorin	Ilorin, Kwara State	Low overall awareness and usage of generative AI tools among biology teachers; minimal adaptation of instructional methods toward AI.	Insufficient training, lack of awareness of AI's pedagogical affordances.

Source: Authors' Meta- Analysis

Position, Synthesis and Implications

Drawing on the above secondary data, we propose the following position:

- 1. High awareness is widespread among biology teachers, but utilisation lags significantly.**
Across multiple studies (Ikot Ekpene, Ilorin, Rivers State, Bauchi), while teachers report awareness of ICT tools and their potential benefits, actual integration into classroom practice is moderate to low. This suggests that awareness and perception, though necessary, are insufficient in themselves to drive utilisation.
- 2. Teacher qualification, training, and internal readiness matter.**
In the North-Central region, academic qualifications significantly predicted ICT skill levels and pedagogical approaches (Akanbi Jimoh et al., 2025). Moreover, Bauchi study (Barde, 2017) stressed that internal readiness (skills, attitudes) is often weak despite reasonable perceptions, indicating that investment in teacher development is essential.

3. **Resource and infrastructural constraints are consistent across regions.** Studies in Nasarawa, Ikot Ekpene, Rivers State, and Ilorin show that many schools particularly in rural or under-resourced areas lack stable power, internet connectivity, digital tools, and technical support, which heavily diminish utilisation.
4. **Perception remains generally positive, but nuanced skepticism exists.** Teachers often believe in the value of ICT or AI tools (e.g., in web-based instruction, AI, etc.), but subtle differences emerge in perception linked to exposure, prior training, and availability of resources. The Jimba et al. (2024) study on generative AI showed awareness and use were low, yet perception is not strongly negative suggesting an opening for growth.
5. **Policy, institutional support, and leadership are critical enabling factors.** Administrative support, school leadership, resource allocation (budget, equipment), ongoing professional development, and alignment of curriculum with technology goals are repeatedly identified as enablers or blockers. Without these, even teachers with high awareness and willingness cannot translate that into utilisation.

Conclusion

The body of empirical research suggests that biology teachers in Nigeria are generally aware of ICT tools and hold positive perceptions about their potential for improving instruction. However, utilisation lags behind due to resource deficiencies, skill gaps, and weak institutional support. In FCT, Abuja, the context is promising but not without challenges. To bridge the awareness-utilisation gap, there must be coordinated policies, investment in infrastructure and teacher development, and effective leadership. Only then can the potential of technology integration be fully realised.

Recommendations

Based on these empirical findings, the authors provided the put forward the following recommendations

1. Develop clear, enforceable policy mandates that embed technology integration in teacher evaluation and curriculum delivery. - Ensure consistent funding for ICT infrastructure in both urban and rural schools, including reliable power, internet access, and hardware/software.
2. Enhance pre-service and in-service training programs emphasising pedagogically meaningful uses of technology (not just tool familiarity), including AI and virtual labs, where feasible. - Embed TPACK (Technological Pedagogical Content Knowledge) frameworks in teacher training curriculum.
3. Provide institutional support: ensure time allowances for teachers to learn and prepare ICT-enabled lessons; allocate budgets for maintenance and technical support. - Encourage peer mentoring and collaborative learning among biology teachers to share effective practices.
4. Partner to supply low-cost, durable ICT tools, especially for schools with limited resources. - Collaborate with the government to offer professional development workshops, perhaps leveraging public-private partnerships to diffuse cost

- 5 Conduct longitudinal studies in FCT as the capital of Nigeria,, to track changes over time in awareness, perception, and utilisation among biology teachers. - Investigate student outcomes related to differing levels of technology integration in biology instruction to build evidence for investment.

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INNOVATIVE TECHNICAL EDUCATION THROUGH AI-DRIVEN ENTREPRENEURSHIP: A REVIEW

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Abstract

This study explores how innovative technical education through AI-driven entrepreneurship can contribute to the development in the 21st century. Traditionally, technical education has been delivered in a way that aims to develop learners with applied skills. However, AI applications, such as smart tutoring systems, adaptive learning environments, predictive analytics, and virtual incubation hubs are poised to change the learning landscape, delivering advanced personalization and improving the development of skills. AI applications are also providing learners with an entrepreneurial mindset and pathways to create jobs and self-sufficiency. The paper provides an exploration of the conceptual basis for AI-driven entrepreneurship applied to technical education while describing the potential of AI in bridging skills gaps, improving employability, and fostering innovation in emerging countries. While the benefits of AI are significant, consequential barriers, such as infrastructure access, high-cost implementation, and ethical considerations also pose considerable barriers. The recommendations include curriculum improvement and reform, capacity building, policy support, and partnerships among education stakeholders. In conclusion, AI-driven entrepreneurship is a paradigm shift that can reposition technical education as an economic resilience and sustainable development generator supported by visionary strategy and engagement.

Keywords: Artificial Intelligence, Technical Education, Entrepreneurship, Innovation, 21st-Century Skills

Introduction

Technical education has long been recognized as a cornerstone of workforce development, innovation, and national competitiveness. It provides learners with the experiential knowledge and applied skills they'll need for many fields, such as construction, manufacturing, engineering, and information technology (Okolie & Igwe, 2021). Most recently, the rapid pace of digital transformation has challenged the expectations of technical education. Educational institutions are under pressure to integrate the latest technologies and potentially entrepreneurial competencies in order to be more responsive to the requirements of the 21st-century workplace. Artificial Intelligence (AI) has become an important transformative resource. Through intelligent automation, predictive analytics, and 'adaptive' learning environments, AI technologies offer the potential to personalize instruction, optimize training, and develop new pathways for skill acquisition (Hwang & Chen, 2023). AI has also become a strategic resource for entrepreneurship by helping innovators and start-ups find business opportunities, maximize operational efficiencies, and make data-driven decisions (Güner-Gültekin *et al.*, 2025).

The field of entrepreneurship in technical education extends far beyond just launching businesses; it facilitates the processes of innovation, addressing problems, and commercialization of an idea. When coupled with understanding AI technologies or engaging with AI applications, entrepreneurship education prepares learners in the vocational / technical area to not only

participate in the job market but maintain the mastery to create jobs, and contribute to economic development. In both developing or advanced economies, this union signifies the relevance of AI enhanced entrepreneurial activities in educational contexts as an important framework for updating the institution of technical education, as well as addressing socio-economic challenges.

AI-Driven Entrepreneurship in Technical Education

AI-driven entrepreneurship is the use of artificial intelligence concepts, tools, systems, and techniques in the pursuit of identifying, developing, and managing entrepreneurial business ventures. It involves the application of AI for market research, product design, customer engagement, financial forecasting, and improved operational processes (Kraus *et al.*, 2022). In the field of technical education, AI-driven entrepreneurship is an instructional and practical framework in which students and educators leverage technologies powered by AI, to innovate, create value, and establish scalable ventures. This lens understands AI technologies as not only an enabler of technology, but a facilitator of learning opportunities in entrepreneurship. For instance, AI deployed as simulation tools can provide learners in technical colleges the ability to prototype ideas, test an idea's viability, and collect real time market trends. Additionally, AI powered entrepreneurial learning platforms - such as smart business incubators or AI enabled entrepreneurship hubs - can provide verticals for collaboration, mentorship, and venture growth amongst learners in technical education (Roundy, 2022). Thus, AI-driven entrepreneurship in technical education transcends just teaching students how to utilize AI; it also integrates AI into the very nature of entrepreneurial thinking, ultimately preparing aspiring professionals to navigate technology-oriented economies, particularly as they become increasingly complex.

AI Applications in Technical and Entrepreneurial Education

The use of Artificial Intelligence has emerged as a strong force for innovation in teaching, learning, and entrepreneurship in technical education. Artificial Intelligence can be applied in practices ranging from classroom delivery to real-world incubators for businesses, thus changing how students learn skills, build ideas, and form those ideas into businesses.

1. **AI in Technical Education:** Adaptive and personalized learning systems have emerged through AI with the ability to accommodate individual learner preferences and requirements. Intelligent tutoring systems, for example, give tailored feedback, track learner progression, and identify necessary additional support required (Holmes *et al.*, 2019). This flexibility enables technical education to move towards more differentiated pathways as opposed to a traditional one-size-fits-all framework based on reliability via an individual learner's strengths and weaknesses. AI-enhanced simulations and virtual laboratories are also becoming more and more popular in technical fields of education including engineering, construction, and electronics. These types of education technologies enable the learner to repetitively practice complex processes, explore troubleshooting errors in the procedural process, and experience a hands-on experience - all without the risk of environmental or financial involvement in physical classrooms (Imran *et al.*, 2024). The combination of these learning environments enables the theoretical knowledge to blur with the procedural skill acquisition in a fast-paced and risk-free learning experience that allows the educator and learner to maintain quality and relevance in technical training systems.

2. **AI in Entrepreneurial Education:** AI applications can enhance creativity, decision-making, and venture management in entrepreneurship education. Predictive analytics toolkits allow for the analysis of market trends, customer preferences, and competitor behavior. These predictive analytics allow learners to accurately assess business opportunities (Ruiz-Real *et al.*, 2021). AI-powered idea generation platforms encourage innovative thinking by providing real-time data-driven ideas about product development and company creation. AI also fills important roles in enabling digital incubation platforms that support business ecosystems (between incubator, mentorship, and crowdfunding). AI-enabled tools can help students generate enterprise business plan, business financial model, and automating marketing processes that may convert class projects into commercial startups (Roundy, 2022). All of these support IDE in expanding entrepreneurship education beyond the confines of theoretical pedagogy, providing an applicable, experience-driven educational modality that is technology and practice-oriented.

Integrating AI Across Education and Entrepreneurship

The intersection of AI applications in technical and entrepreneurial education fosters an energetic space for students to test, create, and commercialize. AI-based project management systems, for instance, enable student teams to collaborate much more effectively on entrepreneurial activities, while natural language processing (NLP) applications can also assist students in developing business proposals and pitching ideas. Such integrations reinforce problem solving, creativity, and resilience which are vital in succeeding in the knowledge economy (Kraus *et al.* 2022).

Benefits and Opportunities

The incorporation of Artificial Intelligence in technical and entrepreneurial education provides substantial benefits for learning and teaching as well as socio-economic development, while simultaneously providing superior quality and opportunities for innovation and employability.

1. **Skill Development and Creativity**

Tools powered by artificial intelligence encourage more profound skill development due to the opportunity for learners to engage in interactive, problem-based learning. Adaptive learning platforms promote skill-building techniques for students, allowing them to develop and master the specific technologies and technical skills at their own pace. AI design software and design simulators encourage creativity and innovative product development (Kumari *et al.*, 2024). Personalization encourages autonomous thinking and equips learners to develop competencies necessary for ever-changing labor markets.

2. **Employability and Workforce Readiness**

A key benefit of embedding AI within technical education is the improvement of employability in graduates. Two significant areas facilitate this benefit. By developing competencies with an AI technique, students are not only gaining digital literacy, but they also improve higher-order thinking skills like problem-solving (Okolie & Igwe, 2021). Secondly, using AI for entrepreneurial learning theoretically can help students develop the skill-set to start their own businesses and create jobs instead of looking for employment (Kraus *et al.*, 2022). The combined value of these opportunities positively impacts students' employability and economic development.

3. Industry Relevance and Innovation

AI enhances cooperation between technical education institutions and industry. Predictive analytics and real-time data processing enable students to carry out projects relevant to industry, which integrates theory with practice (Ruiz-Real *et al.*, 2021). Furthermore, entrepreneurship education supported by AI tools enables students to identify market needs that are unmet, test their business models, and innovate with less risk. This creates opportunities for a technical college or university to be a hub of innovation by preparing graduates who can contribute to the growth and competitiveness of industry.

4. Expanding Access and Inclusivity

Another opportunity is AI's potential to expand access to technical and entrepreneurial education. Intelligent learning platforms and virtual incubation centers reduce geographic and financial barriers and provide students located in underserved geographies access to advanced tools and entrepreneurial ecosystems (Holmes *et al.*, 2019). Expanding access to education and economic participation supports inclusion and aligns with global sustainable development goals.

Challenges and Limitations

While Artificial Intelligence (AI) has the potential to change the landscape of technical and entrepreneurship education, there are numerous challenges and limitations that will inhibit its effective adoption. These challenges and limitations range from infrastructure deficits to ethical dilemmas, all of which will determine how much technical institutions and students can benefit from AI-enabled entrepreneurship.

1. Ethical and Data Privacy Concerns

Data is the foundation of AI systems and is critical for training, decision-making, and prediction. For educational leaders and entrepreneurs, concerns arise regarding data confidentiality, security, and ethical use (Jobin *et al.*, 2019). The misuse of sensitive student data, new business ideas, and market data could occur if proper regulations are not in place. Further, algorithmic injustice can reinforce inequities by disadvantaging certain demographics of learners or entrepreneurs thereby working against the pursuit of making education equitable.

2. Infrastructure and Accessibility Gaps

Numerous technical organizations, especially in developing countries, encounter infrastructural barriers like insufficient internet coverage, failure to maintain an uninterrupted supply of electricity, and inadequate investment in digital infrastructure (Bizzo, 2022). Without these prerequisites, teaching, learning, or entrepreneurship using AI tools cannot be widely integrated. High costs to acquire AI software and hardware remain a deterrent to offering AI in resource-constrained frameworks.

3. Teacher Preparedness and Digital Literacy

In order for educators to successfully incorporate AI-infused tools into their classrooms, they must have a solid understanding of digital skills. However, many teachers have not received training to effectively implement AI platforms for instructional purposes or entrepreneurship training (Holmes *et al.*, 2019). This lack of skill limits the overall effectiveness of the AI

infusion, resulting in resistance from instructors who already see technology as complex and disruptive to traditional teaching.

4. Financial and Sustainability Barriers

Introducing AI systems in technical education comes at a cost, as funding is required for licensing, upkeep, and ongoing up-dates. But institutions with constrained financial resources cannot sustain their AI-based activities after the pilot phase (Güner Gültekin *et al.*, 2025). Unless funding is on an ongoing basis or a public-private partnership model is developed, many of new AI-based entrepreneurial programs are sure to terminate following initial programming phase.

5. Policy and Regulatory Limitations

Additionally, the lack of robust policies and clear regulatory frameworks for the use of AI in education and entrepreneurship remains a challenge. The potential for misuse when AI is used without regulations is a concern, but overly restrictive regulations may limit innovative ideas and opportunities. Regulations and innovative approaches are critical considerations for policymakers trying to encourage AI-driven entrepreneurship in technical education (Roundy, 2022).

Future Directions

1. Policy and Institutional Strategies

The effective incorporation of AI-empowered entrepreneurship into technical education needs supportive policies and institutional models. Governments and educational systems should provide funding to develop digital infrastructure, promote teacher training initiatives, and create policies that facilitate the engagement of higher education institutions with industry and technology vendors. Public-private partnerships can also be instrumental in funding AI initiatives and sustaining entrepreneurship ecosystems at technical colleges.

2. Curriculum Redesign and Pedagogical Innovation

Looking ahead, the redesign of technical education that embeds AI and entrepreneurship as cross-cutting themes should be prioritized. This means including AI tools in project-based learning, innovation hubs, and startup incubation. Emphasizing pedagogical innovation through hands-on learning, critical thinking, and problem-solving is important so that students will develop technical and entrepreneurship skills that will be relevant to future labor markets.

3. Sustainable Strategies for Developing Nations

For developing nations, the implementation of AI in technical education must consider localized challenges such as infrastructure deficits, affordability, and equity. It is possible to use low-cost AI solutions, open source platforms, and mobile based applications, to help bridge access. In addition, regional collaboration and knowledge sharing can contribute to capacity building across the African continent, and reduce duplication of effort.

4. Building Ethical and Inclusive Systems

Future directions should also include a focus on ethical, fair integration of AI. Institutions need to embrace more transparent data policies, protect student and entrepreneurial data

privacy, and carefully address algorithmic bias that may reinforce inequities. Inclusivity should be promoted by adapting AI-driven platforms to support learners from rural or other marginalized communities.

Conclusion

Entrepreneurship driven by artificial intelligence is a potent instrument for enhancing technical education and employment in the 21st century. Artificial intelligence enhances skill acquisition, stimulates creativity, and prepares learners for employment or entrepreneurship. However, to maximize the impact of its application, challenges such as infrastructure gaps, availability of funds, and ethical issues need to be addressed. The way forward is for policymakers, educators, and industry to work collaboratively to create sustainable, inclusive, and innovative solutions that empower learners and strengthen national economies.

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TOWARD GAME-ORIENTED PEDAGOGY IN MATHEMATICS: EXPERT REFLECTIONS ON LUDOMETRIC AND WORD PUZZLE STRATEGIES

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Abstract

Persistent challenges in mathematics education particularly low student achievement, anxiety and declining interest have prompted educators to explore more engaging pedagogical strategies. This paper presents an expert reflection on the potential of Ludometric and Word Puzzle instructional strategies as transformative tools in mathematics classrooms. Drawing from constructivist, gamification and cognitive engagement theories, the paper argues that integrating structured play and puzzle-based tasks can enhance learners' motivation, conceptual understanding and problem-solving skills. The reflections synthesize findings from recent empirical and theoretical studies demonstrating the efficacy of game-oriented learning models (Rizqiyani et al., 2024; Ratnasari and Nugraheni, 2025; Ajdini and Merovci, 2025). It further explores classroom implications, challenges to implementation and strategies for reforming mathematics pedagogy toward active, playful and learner-centered approaches. By adopting a game-oriented pedagogy, mathematics education can move beyond rote learning toward curiosity-driven exploration and meaningful understanding.

Keywords: *Game-Based Learning, Mathematics Education, Ludometric Strategy, Word Puzzle Instruction, Student Achievement, Cognitive Engagement and Pedagogical Innovation*

Introduction

Mathematics education remains a cornerstone of intellectual development, yet it continues to face pressing pedagogical challenges across many educational systems. Persistent reports of poor student performance, low retention and declining interest have generated global concern (Salami and Spangenberg, 2024). Traditional instructional methods often reliant on teacher-centered delivery, memorization and repetitive exercises have proven insufficient in fostering deep understanding or sustained engagement. Consequently, educators and researchers have called for innovative, student-centered instructional strategies that make learning mathematics enjoyable, relatable and conceptually grounded.

One promising response is the adoption of game-oriented pedagogies, particularly those employing Ludometric and Word Puzzle strategies. Ludometric approaches use structured board or digital games, such as Ludo Math or Cheerful Ludo Math, to develop numerical reasoning and problem-solving skills (Ratnasari and Nugraheni, 2025; Issau, Hassan and Zakariyau, 2024). Word puzzles, on the other hand, employ linguistic and logical challenges to strengthen vocabulary, conceptual comprehension and metacognitive engagement (Ebizie, Oraelosi and Nwodo, 2024). The present paper offers expert reflections on these methods as integral components of a broader shift toward game-oriented mathematics pedagogy. It argues that a deliberate integration of such

strategies can not only enhance academic achievement but also reignite students' intrinsic motivation to learn mathematics.

Theoretical Perspective

The conceptual foundation for game-oriented pedagogy lies in:

Constructivist learning theory: constructivist learning theory which posits that knowledge is actively constructed by learners through meaningful experiences. Constructivism emphasizes interaction, discovery and reflection as essential components of learning (Hanghøj *et al.*, 2018). Games, by design, embody these elements: they present challenges, invite experimentation and provide feedback all of which align with constructivist principles.

Gamification theory: Gamification theory extends this by asserting that applying game elements (competition, rewards, levels and collaboration) to non-game contexts can significantly increase learner engagement (Barbaros, Saygi and Sengil-Akar, 2024). Games introduce cognitive disequilibrium, prompting learners to resolve problems through strategic reasoning. This cyclical engagement enhances both retention and transfer of knowledge (Rizqiyani *et al.*, 2024).

Cognitive engagement theory: Cognitive engagement theory supports the idea that motivation and persistence in learning tasks are strengthened when learners perceive them as meaningful and enjoyable (Rojas-Pino *et al.*, 2024). Puzzle-based and ludometric activities stimulate cognitive engagement by blending challenge with curiosity, which encourages perseverance and reflection (Baßeng and Budke, 2024).

From a neurological perspective, engaging in play activates reward pathways associated with dopamine release, improving attention and memory consolidation (Patacsil, 2021). Thus, game-oriented learning not only aligns with pedagogical theories but also resonates with cognitive science findings about how humans learn most effectively.

Ludometric and Word Puzzle Instructional Strategies: Conceptual Overview

Ludometric instruction

Ludometric instruction refers to the use of mathematically structured games—often adaptations of *Ludo*, *Snakes and Ladders*, or other strategy-based board games—to teach mathematical concepts such as number operations, geometry and probability (Rizqiyani *et al.*, 2024). The term derives from *ludo* (play) and *metric* (measurement), implying measurable learning through play. Ratnasari and Nugraheni (2025) developed *Cheerful Ludo Math*, integrating the Team Games Tournament (TGT) model to encourage collaborative problem-solving and peer support in learning arithmetic. Similarly, Issau, Hassan and Zakariyau (2024) found that Ludo-based mathematics instruction significantly improved secondary students' performance in Oyo State, Nigeria, underscoring the method's contextual adaptability.

Word puzzle strategies

Word puzzle strategies, on the other hand, involve crossword puzzles, anagrams, or concept-matching tasks that emphasize mathematical vocabulary and reasoning (Ebizie *et al.*, 2024). These puzzles help students link abstract mathematical terms with their meanings, promoting conceptual fluency and retention (Hidayatulloh and Noerhasmalina, 2025). The integration of language and

logic in puzzles fosters metacognitive awareness learners reflect on their thought processes as they solve problems (Rojas-Pino *et al.*, 2024).

Both strategies promote active participation, peer interaction and formative assessment. As Fuentes Jr. (2024) demonstrated in his study on card-based trigonometry learning, game mechanics can scaffold complex conceptual understanding through repeated engagement and immediate feedback.

Collectively, Ludometric and Word Puzzle strategies encourage what Jensen and Hanghøj (2020) describe as “mathematical play”—the negotiation between structured rules and creative exploration, a process through which deeper understanding emerges.

Expert Reflections on Pedagogical Value

Empirical evidence consistently supports the claim that game-oriented learning enhances mathematics achievement and interest. Salami and Spangenberg (2024) reported that mathematical games significantly improved students’ performance regardless of gender, highlighting their inclusivity. Similarly, Ajdini and Merovci (2025) observed that teachers perceive game-based learning as an effective tool for stimulating motivation and conceptual understanding among diverse learners.

From a pedagogical standpoint, motivation is perhaps the most significant benefit. When learning is enjoyable, students approach mathematical challenges with curiosity rather than anxiety. The sense of autonomy inherent in game participation enhances intrinsic motivation (Rizqiyani *et al.*, 2024). Moreover, games encourage collaboration, where learners share strategies and develop communication skills key competencies for 21st-century education (Hanghøj *et al.*, 2018).

The reflective element embedded in puzzle-solving further enhances critical thinking and metacognition. Rojas-Pino *et al.* (2024) emphasize that reflection is crucial to transferring in-game learning to academic contexts. Similarly, Baßeng and Budke (2024) demonstrated how reflection diaries in game-based learning environments promote awareness of cognitive processes, an insight that can be applied effectively in mathematics classrooms.

Game-oriented instruction also cultivates problem-solving and persistence. By facing incremental challenges, learners experience manageable failure and iterative success, which fosters resilience (Barg, 2024). Word puzzles, specifically, support conceptual reinforcement—students repeatedly engage with key terms, ensuring mastery (Ebizie *et al.*, 2024).

Lastly, these strategies create emotionally positive learning environments. Positive emotions facilitate cognitive processing and reduce mathematics anxiety (Patacsil, 2021). Collectively, these reflections indicate that Ludometric and Word Puzzle methods can humanize mathematics education, making it both cognitively rigorous and affectively supportive.

Table 1: Summary of Empirical and Conceptual Studies on Game-Oriented Mathematics Instruction (2018–2025)

S/N	Author(s) Year	and Location Area of Study	Research Methodology Sample	/ Results / Findings
1	Hanghøj et al. (2018)	Denmark	Conceptual design-based analysis of game-oriented learning	Identified key domains and practices for integrating games into education, emphasizing student engagement, reflection and problem-solving.
2	Kulikowski (2019)	USA	Historical and reflective study	Highlighted the early evolution of artificial intelligence for educational support, emphasizing computational assistance for learning and reflection.
3	Jensen and Hanghøj (2020)	Denmark	Design-based study using <i>Minecraft</i> ; secondary students	Found that students connected mathematical thinking between game environments and formal classroom learning, enhancing conceptual understanding.
4	Patacsil (2021)	Philippines	Review and classroom-based exploration	Demonstrated that games and puzzles improve mathematics learning motivation and concept mastery among elementary and high school students.
5	Rizqiyani et al. (2024)	Indonesia	Literature review	Concluded that Ludo game-based learning effectively enhances students' spatial understanding and engagement in mathematics.
6	Salami and Spangenberg (2024)	Nigeria	Quasi-experimental; Senior Secondary Students	Found that mathematical games significantly improved achievement across genders, though female students showed slightly higher engagement levels.

S/N	Author(s) Year	and Location Area of Study	Research Methodology Sample	/ Results / Findings
7	Issau et al. (2024)	Nigeria (Ogbomoso, Oyo State)	Quasi-experimental; Senior Secondary Students	Reported that Ludo game-based instruction improved students' academic performance compared to traditional methods.
8	Ebizie et al. (2024)	Nigeria (Nsukka Education Zone)	Quasi-experimental; Primary pupils	Puzzle game-based approach enhanced pupils' achievement in mathematics, promoting active participation and interest.
9	Barg (2024)	Sweden	Qualitative hermeneutic analysis (Master's thesis)	Introduced the concept of <i>Ludo-Hermeneutics</i> —interpreting digital games through reflection and meaning-making in learning contexts.
10	Baßeng and Budke (2024)	Germany	Experimental classroom study; geography learners	Found reflection diaries integrated with games promoted metacognitive awareness and deeper learning.
11	Barbaros et al. (2024)	Turkey	Systematic literature review	Identified consistent evidence that game-based learning enhances motivation, collaboration and mathematical reasoning across educational levels.
12	Fuentes Jr (2024)	Philippines	Experimental; High school students	Use of <i>TrigOno Card Game</i> improved mastery of trigonometric identities through repetition and peer interaction.
13	Rojas-Pino et al. (2024)	USA (Stanford University)	Experimental; digital puzzle-based learning	Found that structured reflection after gameplay significantly improved problem-solving and retention.

S/N	Author(s) Year	and Location Area of Study	Research Methodology Sample	/ Results / Findings
14	Ratnasari and Nugraheni (2025)	Indonesia	Developmental research; Fifth grade students	Developed <i>Cheerful Ludo Math</i> integrated with TGT (Teams-Games-Tournament) model; improved problem-solving and collaborative learning outcomes.
15	Hidayatulloh and Noerhasmalina (2025)	Indonesia	Quasi-experimental; Middle school students	Showed that puzzle-based learning enhanced mathematics problem-solving skills significantly more than traditional instruction.
16	Ajdini and Merovci (2025)	Kosovo	Survey; mathematics teachers	Found that teachers generally held positive perceptions of game-based learning but required more training and curriculum support for implementation.

Implementation Challenges and Considerations

While the pedagogical value of game-oriented approaches is evident, their implementation presents practical challenges. The first major issue is **teacher readiness**. Many mathematics teachers lack training in game-based instructional design or harbor misconceptions that games undermine academic rigor (Ajdini and Merovci, 2025). This underscores the need for professional development programs that equip teachers with skills to design, adapt and facilitate Ludometric and Word Puzzle lessons effectively.

Second, there is the issue of **curriculum alignment**. National curricula often emphasize standardized testing and procedural learning, leaving little room for experimental or playful instruction (Salami and Spangenberg, 2024). Integrating games requires flexibility within the curriculum to allow exploratory learning without compromising content coverage.

Third, **resource availability** remains a concern. While some Ludometric games are low-cost and locally adaptable, others may require materials, technology, or teacher support that schools lack (Issau *et al.*, 2024). Developing open-access, culturally relevant game resources can mitigate this challenge.

Fourth, **assessment** in game-based learning poses conceptual difficulties. Traditional summative tests may not capture the skills developed through games such as collaboration, reasoning and creativity. Therefore, alternative assessments such as reflective journals, peer evaluations, or performance-based tasks are recommended (Baßeng and Budke, 2024).

Lastly, **student diversity** must be considered. Not all learners engage with games in the same way; some may find competition stressful or struggle with language-based puzzles. Adopting differentiated instruction and inclusive game design principles can ensure equitable learning opportunities (Barbaros *et al.*, 2024).

Implications for Mathematics Education Reform

The integration of Ludometric and Word Puzzle instructional strategies has broader implications for educational reform. First, it supports the shift toward 21st-century competencies, such as collaboration, creativity, critical thinking and communication (Hanghøj *et al.*, 2018). Game-based learning naturally cultivates these skills through interaction and reflection.

Second, it aligns with global calls for active and inquiry-based pedagogy in STEM education (Hidayatulloh and Noerhasmalina, 2025). Instead of viewing mathematics as abstract and detached, game-oriented approaches situate learning within meaningful, playful contexts that stimulate imagination and exploration.

Third, such strategies encourage technological integration. Digital adaptations of Ludometric games, for example, can promote hybrid learning models compatible with modern classrooms. Kulikowski (2019) notes that technological augmentation of traditional practices enhances personalization and engagement—principles that apply equally to educational games.

Moreover, reforming teacher education to include game-based pedagogical training is crucial. Pre-service and in-service programs should emphasize the design, evaluation and implementation of games in mathematics teaching. As Fuentes Jr. (2024) showed, simple instructional games can transform abstract topics like trigonometric identities into interactive, mastery-based experiences. Finally, educational reform must be guided by cultural contextualization. Game designs should reflect learners' socio-cultural realities to enhance relevance and motivation (Issau *et al.*, 2024). Locally designed Ludometric activities can connect mathematics concepts to everyday life—market bargaining, sports and traditional board games—making learning authentic and engaging.

Conclusion

This opinion paper has argued that Ludometric and Word Puzzle instructional strategies hold significant potential for transforming mathematics education into a more engaging, reflective and effective learning experience. Supported by constructivist and gamification theories, these approaches foster deeper understanding, motivation and retention by turning abstract mathematical concepts into meaningful play experiences.

While implementation challenges persist especially regarding teacher readiness, curriculum flexibility and assessment these can be addressed through deliberate reform in teacher education and resource design. The evidence reviewed (Rizqiyani *et al.*, 2024; Ajdini and Merovci, 2025; Ebizie *et al.*, 2024) suggests that when game-oriented methods are purposefully integrated, students not only perform better but also develop positive attitudes toward mathematics.

Ultimately, mathematics education must evolve from a paradigm of memorization to one of meaningful engagement. Ludometric and Word Puzzle strategies exemplify how playful learning can cultivate both intellectual rigor and joy, aligning with the goals of holistic, 21st-century education. A game-oriented pedagogy thus represents not a diversion from mathematics learning, but its most human-centered and enduring form.

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COMPETENCY OF LECTURERS IN INTEGRATING DIGITAL SKILLS FOR INSTRUCTION IN BUILDING TECHNOLOGY IN POLYTECHNICS IN NORTH-CENTRAL NIGERIA

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Abstract

The study assessed the competency of lecturers in integrating digital skills for instruction in Building Technology in Polytechnics in North-Central Nigeria. The research was guided by two objectives which examined the types of digital tools used and the level of lecturers' digital skills competence. A descriptive survey research design was adopted, and the entire population of 139 lecturers and 11 Heads of Department from selected polytechnics in the North-Central geopolitical zone was surveyed using a census sampling technique. Data was collected using a structured questionnaire titled "Questionnaire on Teachers' Digital Skills Integration (QTDSI)" and analyzed using mean, standard deviation, and z-test. The findings revealed a moderate level of digital competence among lecturers. While they were competent in using basic digital tools like Computer-Aided Design (CAD), productivity software, and Learning Management Systems (LMS), there was a significant deficiency in the integration of advanced, industry-disruptive technologies such as VR, Augmented Reality (AR), and drones. Furthermore, lecturers' competence was predominantly operational rather than pedagogical, showing low proficiency in critical areas like developing online assessments, fostering collaborative online learning, curating digital resources, and evaluating the effectiveness of digital tools. Key challenges identified included inadequate infrastructure, insufficient and non-pedagogically focused training, and a lack of institutional support. The study concludes that the current digital competency level of Building Technology lecturers is insufficient to fully prepare graduates for the modern construction industry. It recommends the implementation of pedagogically-focused professional development grounded in the TPACK framework, strategic investment in digital infrastructure, and the establishment of robust technical and peer-support systems to enhance the quality of digital skills integration in Building Technology education.

Keywords: Digital Skills, Competency, Integration, Building Technology, Lecturers.

Introduction

In a world driven by technological advancement, the integration of digital skills in education has become a critical necessity for preparing students for the modern workforce. Digital skills have emerged as a pivotal focus in contemporary education policy and practice, shaping how learning is designed, delivered, and assessed. These skills go beyond the basic capacity to operate computers or navigate the internet; they encompass a broader set of competencies, including the ability to critically select, adapt, and evaluate digital resources to meet specific learning objectives. In the education sector, particularly in technical and vocational fields, these competencies also involve the pedagogical expertise required to integrate technology meaningfully into teaching and learning (Adebowale & Adedapo, 2022). This reflects a shift from viewing digital skill literacy as

an optional add-on to recognizing it as an essential component of professional preparedness in the 21st century in Building Technology.

Building Technology is an academic and professional discipline which plays a crucial role in preparing technologists and technicians for careers in construction, architectural drafting, and project management. The field traditionally emphasizes on construction processes, materials science, design principles, and site supervision (Adeyemi & Adeyinka, 2022). However, the nature of the construction industry is changing rapidly, with digital techniques ranging from computer-aided design (CAD) and Building Information Modelling (BIM) to 3D visualization, virtual reality simulations, and digital project management platforms becoming integral to industry workflows. Proficiency in these technologies is no longer a niche skill but a core professional requirement in Building Technology in Polytechnics.

Building Technology particularly in Nigerian polytechnics faces the imperative to evolve beyond traditional workshop-based training to meet these emerging demands. While hands-on demonstrations and site-based learning remain important for foundational skills, polytechnics must integrate digital skill into their curricula to ensure graduates meet industry standards for modern construction practices (Eze *et al.*, 2021). This shift positions polytechnics as critical hubs for developing a technologically adept workforce capable of navigating complex construction ecosystems. Polytechnics in Nigeria need to be equipped to deliver the essential training to meet requires industry's rapid digitization demand with the type of digital tools.

To achieve this demand, lecturers' usage on the diverse types of digital tools commonly used are integral to contemporary Building Technology instruction. Building Information Modelling (BIM) software such as Autodesk Revit and ArchiCAD allows students to create detailed, data-rich 3D models, enabling more accurate design coordination and reducing errors before physical construction begins. Virtual reality (VR) and augmented reality (AR) platforms provide immersive simulations of construction sites, offering safe, cost-effective environments for skill development in spatial awareness, safety protocols, and complex project visualization. Computer-aided design (CAD) applications, once a significant technological leap in themselves, remain essential for precision drafting, while modern project management software like Microsoft Project equips students with the ability to plan, schedule, and monitor projects in real time. Sacks *et al.* (2018) highlight that these tools collectively facilitate collaborative design processes, streamline communication among stakeholders, and enhance problem-solving capabilities in ways that traditional teaching methods cannot fully replicate. The effective use of these tools by lecturers' digital skill competence is crucial for delivering a curriculum that is relevant and aligned with industry standards.

The level of teachers' digital skills competence in polytechnics, is a critical factor influencing the quality education of Building Technology students. The successful adoption and impact of digital tools in Building Technology is heavily dependent on the digital skills competence of Lecturers (Aghimien *et al.*, 2020). Even the most advanced technologies cannot transform teaching if lecturers lack the ability to apply them strategically in their instruction. In Nigerian polytechnics, studies have shown that while Building Technology lecturers generally possess foundational computer literacy such as proficiency in word processing, basic spreadsheet use, and internet navigation only a small fraction, estimated between 20–35%, demonstrate proficiency in advanced

applications like Building Information Modelling (BIM), parametric design tools, or data-driven construction optimization platforms (Olutola & Adekunjo, 2020). This gap between basic digital familiarity and high-level professional application represents a significant bottleneck in realizing the full pedagogical potential of digital resources. This skills gap result from insufficient training opportunities, limited access to modern equipment, and a lack of institutional support, which ultimately affects the quality of instruction and the preparedness of graduates for the workforce (Yusuf & Afolabi, 2021). These challenges directly impact the integration of digital tools by lecturers in teaching Building Technology.

Ultimately, overcoming these structural and skill-based barriers is not merely a matter of technological investment but of systemic transformation. A coordinated approach involving government agencies, industry stakeholders, and educational institutions is essential to modernizing Building Technology. Such efforts would ensure that Nigerian polytechnic graduates possess both the traditional craftsmanship and digital skill competency required to thrive in a construction industry that is increasingly defined by innovation, precision, and global competitiveness.

Statement of the Problem

The rapid digital transformation of the global construction industry demands Building Technology graduates proficient in advanced technologies like Building Information Modelling (BIM), virtual/augmented reality (VR/AR), and data-driven project management. Nigerian polytechnics are mandated to produce industry-ready Building Technology professionals, but fail to equip lecturers with the necessary digital competencies to deliver such training, jeopardizing graduate employability and national development goals.

Compounding this problem is the limited availability of digital resources. Furthermore, fear of technology, low confidence, lack of training programs, Inadequate funding and absence of clear digital education policies impede teachers' willingness and capacity to adopt new digital tools (Onanuga & Saka, 2025). If unaddressed, these challenges will leave students ill-prepared for a technology-intensive construction industry, diminishing their job prospects and stalling the sector's growth. This study, therefore, assesses competency of lecturers in integrating digital skills for instruction in Building Technology in Polytechnics in North-Central Nigeria.

Aim and Objectives of the Study

The aim of the study is to assess competency of lecturers in integrating digital skills for instruction in Building Technology in Polytechnics in North-Central Nigeria. The objectives of the study are to determine the;

- i. types of digital tools commonly used by lecturers in the training of Building Technology students.
- ii. level of lecturers' digital skills competence in the training of Building Technology students

Research Questions

The following questions were raised to guide the study;

- i. what are the types of digital tools commonly used by lecturers in the training of Building Technology students?

- ii. What is the level of lecturers' digital skills competence in the training of Building Technology students?

Hypotheses

The following hypotheses are formulated and will be tested at 0.05 level of significance;

H₀₁: There is no significant difference in the mean ratings between Head of Department and lecturers as regard the types of digital tools commonly used by lecturers in the training of Building Technology students

H₀₂: There is no significant difference in the mean ratings between Head of Department and lecturers as regard to the level of lecturers' digital skills competence in the training of building technology students

Literature Review

Theoretical framework of the Study

The study will be focusing on two theoretical framework which are Technological pedagogical content knowledge (TPACK) and Diffusion of Innovation (DOI) Theories.

Technological pedagogical content knowledge (TPACK) theory

The Technological Pedagogical Content Knowledge (TPACK) framework is a theoretical model that explains the knowledge base lecturers need to effectively integrate technology into their teaching. Developed by Mishra and Koehler (2006), TPACK builds upon Lee Shulman's (1986) concept of Pedagogical Content Knowledge (PCK) by adding technology as an essential component. The framework emphasizes the complex interplay between three core knowledge domains: Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK).

The TPACK framework consists of seven interconnected knowledge domains:

1. Content Knowledge (CK) – Deep understanding of the subject matter being taught (e.g., mathematics, science, history).
2. Pedagogical Knowledge (PK) – Knowledge of teaching methods, classroom management, and learning theories.
3. Technological Knowledge (TK) – Understanding of digital tools and technologies that can enhance learning (e.g., interactive whiteboards, learning management systems, AI tools).
4. Pedagogical Content Knowledge (PCK) – The intersection of pedagogy and content, focusing on how to teach specific subjects effectively.
5. Technological Content Knowledge (TCK) – Knowledge of how technology can represent and enhance subject matter (e.g., simulations for science, graphing calculators for math).

6. Technological Pedagogical Knowledge (TPK) – Understanding how different technologies can support various teaching strategies (e.g., using discussion forums for collaborative learning).
7. Technological Pedagogical Content Knowledge (TPACK) – The integration of all three domains, allowing lecturers to design effective, technology-enhanced learning experiences.

TPACK (Technological Pedagogical Content Knowledge) is crucial in education as it provides a framework for lecturers to effectively integrate technology into their teaching, enhancing student learning and preparing them for a technology-driven world. It highlights the interconnectedness of technological, pedagogical, and content knowledge, emphasizing that technology should be used purposefully to support teaching and learning. It helps lecturers select appropriate technologies to improve student engagement and understanding. Prepares students for a digital world by integrating critical thinking, collaboration, and digital literacy. Promotes creative lesson planning by combining pedagogy, content, and technology. Allows for differentiated instruction through adaptive technologies.

Historical development of polytechnics in Nigeria

Polytechnics in Nigeria were established to provide technical and vocational education, equipping students with practical skills for industrial and technological development. Unlike universities, which focus more on theoretical knowledge, polytechnics emphasize hands-on training in engineering, applied sciences, and vocational disciplines. Polytechnics remain vital for Nigeria's technological and industrial growth. To strengthen them, the government and stakeholders must upgrade facilities to meet global standards. Enhance industry partnerships for practical training and employment opportunities. Promote parity between polytechnic and university qualifications to eliminate discrimination. Encourage research and innovation in renewable energy, construction tech, and digital skills (NBTE, 2020).

The evolution of polytechnics in Nigeria reflects the country's efforts to bridge the skills gap and promote self-reliance in technical manpower. Before Nigeria's independence in 1960, technical education was largely informal, with skills acquired through apprenticeships (Federal Ministry of Education, 2013). The colonial government established a few technical schools, such as:

- i. Yaba Higher College – The first post-secondary technical institution, offering courses in engineering, medicine, and agriculture in 1932.
- ii. Technical colleges in Lagos, Kaduna, and Enugu – Provided vocational training for artisans and craftsmen.

After independence, Nigeria recognized the need for a structured technical education system to support industrialization. Establishment of the first polytechnics:

- i. Kaduna Polytechnic – Originally a technical college before upgrading in 1968.
- ii. The Polytechnic, Ibadan – The first full-fledged polytechnic in Nigeria, 1970.
- iii. Institute of Management and Technology (IMT), Enugu, 1973

Government policies:

National Policy on Education – Emphasized technical and vocational education (TVET) as critical for national development in 1977.

Establishment of the National Board for Technical Education (NBTE) – To regulate and standardize polytechnic education in 1977.

The oil boom of the 1970s led to increased investment in technical education. More polytechnics were established, including:

- i. Lagos State Polytechnic in 1978
- ii. Auchu Polytechnic (1973, upgraded in 1980s)
- iii. Federal Polytechnic, Nekede in 1978
- iv. State-owned polytechnics – Many state governments established their own institutions to expand access.

The reforms and modernization of polytechnics from (2000s – Present). In the 21st century, efforts were made to reposition polytechnics as centers of innovation and technological advancement:

- i. Introduction of Higher National Diploma (HND) to Bachelor of Technology (B.Tech) conversion programs – Allowing polytechnic graduates to earn degrees.
- ii. Accreditation and quality assurance – The NBTE strengthened curriculum standards.
- iii. Emergence of private polytechnics – Institutions like Grace Polytechnic and Heritage Polytechnic expanded access.
- iv. Technology integration – Polytechnics began adopting digital tools in engineering, construction, and ICT programs.

Building Technology Programme

Building Technology programmes in polytechnics in Nigeria aim to train individuals to become proficient in the science, technology, and practice of building construction and management. These programs typically focus on the practical aspects of building, preparing graduates for entry-level roles in the construction industry, architectural firms, and related fields. Building Technology programs in Polytechnics focus on practical, hands-on skills to prepare graduates for various roles in the construction industry, including construction supervision, material management, and basic structural design. These programs often cover topics like construction materials, building codes, and the process of building from setting out to final completion. The programmes include National Diploma 1 (ND1), National Diploma 2 (ND2), Higher National Diploma 1 (HND1) and Higher National Diploma 2 (HND2) (Federal Ministry of Education, 2013)

Building technology provide tools, materials, systems, and methods used in the design, construction, and operation of buildings. It includes everything from structural systems (like steel and concrete frameworks) to mechanical, electrical, and plumbing (MEP) systems, insulation, lighting, HVAC, and smart technologies. Modern building technology focuses on improving efficiency, safety, sustainability, and comfort. Innovations like prefabrication, green materials, energy-efficient systems, and smart building automation are now standard in many projects. In short, building technology is what turns architectural ideas into functional, durable, and livable spaces (NBTE, 2020).

Applications of digital technologies in education

Digital technologies have emerged as transformative tools in education, offering new possibilities for instructional delivery, content development, and collaborative learning. Their integration has redefined how lecturers create and disseminate learning materials, while also reshaping how

students engage with content and interact within academic environments (Alieto *et al.*, 2024). The global expansion of the internet and the proliferation of smart devices have ushered in a new era in education, requiring lecturers and instructional designers to fully harness these technologies to make high-quality, accessible education a reality for all learners (Opeyemi *et al.*, 2019).

In Building Technology education, digital tools such as Computer-Aided Design (CAD), Building Information Modeling (BIM), and online simulation software are essential not only for teaching technical concepts but also for aligning training with industry standards. These tools enhance the delivery of content and foster creativity among students, encouraging them to explore construction principles beyond traditional classroom settings (Peachey, 2018).

The use of remote learning technologies including TV, radio, online platforms, and mobile applications demonstrated widespread adaptability during periods of educational disruption, such as the COVID-19 pandemic. These platforms provided learners with continuous access to instructional content, improved information retention, and enabled real-time sharing and collaboration (Zhorova *et al.*, 2022). As a result, education became more dynamic, interactive, and student-centered. With rapid advancements in educational technology, it has become essential for lecturers particularly those in technical and vocational fields to be digitally competent. The ability to navigate and integrate various digital devices and platforms, including smartphones, tablets, and online educational resources, is now fundamental. Teachers must also ensure their instructional materials are engaging, up-to-date, and responsive to the learning needs of their students (Jolselt, 2019).

The integration of e-learning platforms, mobile-compatible resources, and interactive content such as animations, simulations, and gamified learning modules enhances student engagement and supports individualized learning. In Building Technology training, these innovations provide realistic, hands-on experiences that mirror workplace scenarios, thereby strengthening the connection between classroom learning and practical application (Zhorova *et al.*, 2022).

Moreover, the adoption of data-driven educational technologies such as learning analytics and performance tracking systems enables institutions to assess student and teacher performance more effectively. This insight is critical in virtual classrooms, online assessments, and other digital learning environments where ongoing evaluation and feedback are essential for improving educational outcomes (Benedict *et al.*, 2024).

Teachers' digital skills competence

Teachers' digital skills competence refers to the essential knowledge, skills, and attitudes needed to effectively integrate digital tools and technologies into teaching and learning processes. This competence encompasses a range of digital literacies including information management, communication, digital content creation, simulation softwares, online quizzes, audio-visual tools, e-learning platforms, safety, and problem-solving that are particularly vital in technical and vocational disciplines like Building Technology (Ayeni *et al.*, 2024). As the educational landscape undergoes rapid digitization, the ability of lecturers to harness contemporary technologies becomes a prerequisite for preparing students for a digitally-driven construction and engineering workforce. The integration of digital skills for building Technology lecturers include building information modeling (BIM), computer-aided design (CAD), simulation software, virtual/augmented reality, and digital construction tools which has redefined pedagogical expectations. Teachers in this

discipline must not only understand and use these technologies proficiently but also adapt them to pedagogical goals, enhancing students' professional readiness for the industry (Zhang *et al.*, 2020). The shift to a digital-first approach presents a dual challenge for Teachers:

- ii. Developing their own digital competencies to stay current with evolving industry standards.
- iii. Transmitting these competencies to students in meaningful and practical ways, ensuring they are equipped to operate in modern construction environments.

Research shows that although digital competence has been embedded into curriculum frameworks and educational policies, there is still a lack of clear guidance and institutional support for systematically developing teacher-specific digital competence, especially in vocational education such as building technology. Often, the success of such initiatives depends on individual enthusiasm rather than structured programmatic efforts. Teacher digital skill integration especially in technical subjects of building technology, must provide comprehensive and practical digital training that aligns with current industrial practices (Lawrence & Tar, 2018; Oguguo *et al.*, 2023). This includes:

- i. Exposure to real-world software and hardware tools used in construction and building design.
- ii. Collaborative projects that mirror on-site workflows.
- iii. The use of digital platforms for assessment, feedback, and student engagement.
- iv. Continuous professional development tailored to technological advancements in the built environment.
- v. Updating of digital resources regularly to keep them relevant
- vi. Teaching students how to use digital tools for design and drafting
- vii. Inclusion of online collaborative tools in group assignments
- viii. Use of digital tools to evaluate student projects or assignments
- ix. Providing feedback to students using digital platforms
- x. Use of computer-aided design (CAD) software in practical lessons

The COVID-19 pandemic further underscored the urgency of digital competence, revealing disparities in access, institutional readiness, and pedagogical adaptation. Despite efforts to provide online alternatives, many teacher education programs lacked the robust infrastructure or coherent strategy to support digital instruction, particularly in hands-on disciplines like Building Technology. In response, specialized training, institutional investment, and cross-sector collaboration between schools and industry are essential. Supervising lecturers must be upskilled, digital infrastructure must be enhanced, and curriculum content should reflect both technical depth and digital fluency. Ultimately, a digitally competent Building Technology teacher is not just a transmitter of knowledge, but a facilitator of skills that empower students to innovate, collaborate, and thrive in a smart, interconnected construction sector (Chukwuemeka & Samaila, 2020).

Teachers' digital skills competence refers to the integrated set of knowledge, technical abilities, attitudes, and pedagogical strategies required to effectively leverage digital technologies for enhancing teaching and learning—particularly within specialized disciplines such as building technology. In today's rapidly digitizing educational landscape, such competence is no longer optional but a fundamental prerequisite for professional relevance and instructional effectiveness (Mtshali *et al.*, 2020). However, despite its recognized importance, research indicates that teacher

education programs often fall short in developing these skills to the depth and breadth required for real-world classroom application.

It was found that many newly qualified lecturers expressed dissatisfaction with the digital training received during their initial education, particularly in its lack of practical classroom integration (Danner and Pessu, 2013). Similarly, Ogunbodede et al. (2023) note that digital competence is frequently fragmented in teacher training programs—reduced to basic tasks such as simple internet searches—rather than embedded meaningfully into pedagogical practice. This gap between expectation and preparation is especially critical in technical disciplines like building technology, where effective teaching increasingly depends on the integration of tools such as CAD software, simulation platforms, and digital measurement systems. Teachers in this domain must therefore not only master these tools but also apply them in ways that align with sound pedagogical principles (Opeyemi *et al.*, 2019), making digital competence both a technological and a pedagogical attribute.

The importance of professional development in bridging this competence gap is widely acknowledged. Ogunbodede et al. (2023) report significant variation in lecturers' digital skills, influenced by factors such as age, teaching experience, and subject area. Interestingly, while 84% of lecturers believed they possessed the necessary digital skills, only a small proportion demonstrated advanced proficiency. Older lecturers tended to have weaker skills, highlighting the need for continuous, targeted professional development. Nevertheless, the prevalence of positive attitudes toward digital learning, even among those with lower proficiency, offers a promising foundation for upskilling initiatives.

Several models have been proposed to support lecturers' digital competence development. Alieto *et al.* (2024) outline five core areas: (1) inspiring students in a digital environment, (2) designing digital learning experiences, (3) creating digitally enriched workspaces, (4) promoting digital citizenship, and (5) engaging in ongoing professional development. Ferrari (2013) contributes a comprehensive framework encompassing five areas: information, communication, content creation, digital safety, and problem-solving—categories that align with European standards and provide a foundational reference for building technology lecturers.

Furthermore, effective digital competence development requires systemic support and institutional commitment. Ogunbodede *et al.* (2023) found that many teacher education programs lack a strategic approach to digital skill development and often rely on individual staff enthusiasm rather than structured training initiatives. Cooperation between teacher training institutions and practical placement schools is also insufficient, despite the clear need for shared standards and upgraded digital infrastructure.

Promising practices include the use of experienced digital-savvy lecturers as mentors, integration of pedagogical ICT frameworks in curriculum design and promotion of reflective digital literacy attitudes among lecturers (Omorobi *et al.*, 2022). For building technology, this also means familiarizing pre-service and in-service lecturers with domain-specific tools (e.g., BIM software, virtual labs) and strategies for engaging students in digital construction simulations, safety training modules, and collaborative design platforms.

Research Methodology

This study adopted a descriptive survey research design. The study was conducted in the North-Central geopolitical zone of Nigeria, which includes the following states: Benue, Kogi, Kwara, Nasarawa, Niger, Plateau, and the Federal Capital Territory (FCT). The total population of the study is One Hundred and Fifty (150) respondents which comprises of all lecturers and Head of Department in Building Technology courses. This study adopted a census sampling technique. The data collected were organised and analysed in line with the research questions and hypotheses formulated for the study. Mean, standard deviation and z-test was used as the statistical tools for data analysis.

Results

Research question one

What are the types of digital tools commonly used by lecturers in the training of Building Technology students?

The answer to research question one is presented in Table 1

Table 1: Mean ratings of the respondents on the types of digital tools commonly used by lecturers in the training of Building Technology students.

S/N	ITEM	X ₁ N ₁ =11	X ₂ N ₂ =139	X N=150	SD	Remark
1.	Computer-Aided Design (CAD) software for drafting and drawing lessons such as Autocad	3.3	3.15	3.22	0.47	Agreed
2.	Utilisation of virtual reality (VR) tools for immersive construction simulations	2.45	2.3	2.38	0.82	Disagreed
3.	Application of 3D modeling software like Revit or SketchUp in practical sessions	2.9	2.75	2.83	0.69	Agreed
4.	Building Information Modeling (BIM) in project-based learning	2.6	2.45	2.53	0.61	Agreed
5.	Project management software (e.g. MS Project) to teach scheduling	2.75	2.6	2.67	0.34	Agreed
6.	Construction simulation software	2.4	2.2	2.3	0.34	Disagreed
7.	Digital laser measuring tools	2.65	2.5	2.58	0.28	Agreed
8.	Online video tutorials to complement classroom training	3.1	3.25	3.17	0.77	Agreed
9.	Learning management systems (LMS) like Moodle or Google Classroom	3.05	3	3.02	0.61	Agreed
10.	Students using digital quizzes and online tests	3	2.9	2.95	0.67	Agreed
11.	Architectural visualization tools (e.g., Lumion) for rendering designs	2.5	2.4	2.45	0.26	Disagreed
12.	Drone technology for site mapping and inspection activities	2.3	2.1	2.2	0.83	Disagreed
13.	Augmented reality (AR) to enhance on-site training	2.35	2.2	2.28	0.75	Disagreed
14.	Cost estimation with spreadsheets and construction databases	2.8	2.7	2.75	0.38	Agreed
15.	Digital cameras to document construction stages	3.1	3.05	3.08	0.36	Agreed

S/N	ITEM	X ₁ N ₁ =11	X ₂ N ₂ =139	X N=150	SD	Remark
16.	Digital drawing tablets to teach drafting and design	2.7	2.55	2.62	0.36	Agreed
17.	Online collaboration platforms (e.g. Trello, Padlet)	2.95	2.85	2.9	0.43	Agreed
18.	Educational YouTube channels on construction practices	3.15	3.3	3.22	0.56	Agreed
19.	Presentation tools like PowerPoint	3.4	3.35	3.38	0.51	Agreed
20.	E-textbooks and digital reading materials	3.25	3.1	3.17	0.42	Agreed
21.	Construction software webinars for professional development	2.85	2.7	2.78	0.62	Agreed
22.	Internet for sourcing new construction techniques	3.45	3.4	3.42	0.33	Agreed
23.	Interactive whiteboards or smartboards	2.95	2.85	2.9	0.43	Agreed
	Grand Average			2.82	0.51	Agreed

Keys: N₁= Number of Head of Departments, N₂= Number of Lecturers, X₁ = Mean of Head of Departments, X₂ = Mean of Lecturers, X_T = Average Mean of head of Department and Lecturers, SD = Standard Deviation

The result in Table 1 shows the mean ratings of the respondents on the types of digital tools commonly used by lecturers in the training of Building Technology students. The result revealed that item 1,3-5, 7-10, 14-23 agreed while item 2,6,11-13 disagreed on the the types of digital tools commonly used by lecturers in the training of Building Technology students. The grand average of 2.82 indicates that, respondents agreed that a range of digital tools are used in the training of Building Technology students, which is also implies that the level of usage is moderate rather than high.

Research question two

What is the level of lecturers' digital skills competence in the training of Building Technology students?

The answer to research question two is presented in Table 2.

Table 2: Mean ratings from the respondents on the level of lecturers' digital skills competence in the training of Building Technology students

S/N	ITEM	X ₁ N ₁ =11	X ₂ N ₂ =139	X N=150	SD	Remark
1.	Confidence in operating a computer for instructional purposes	2.62	2.37	2.5	0.39	Competence
2.	Usage of basic productivity software (e.g., Microsoft Word, PowerPoint, Excel) for teaching tasks	3.43	3.5	3.46	0.48	Competence
3.	Regular use of digital projectors or smartboards during Building Technology lessons	3.12	2.89	3	0.5	Competence
4.	Troubleshooting minor hardware and software problems on classroom devices	2.94	2.59	2.76	0.33	Competence
5.	Ability to use internet browsers effectively to access teaching resources	2.32	2.69	2.5	0.69	Competence
6.	Ability to search, select, and evaluate digital resources relevant to Building Technology topics	2.32	2.26	2.29	0.6	Low competence
7.	Organising digital content and materials for easy access by students	2.18	2.2	2.19	0.67	Low competence
8.	Regular update of teaching content with current information from digital sources	3.31	2.95	3.13	0.65	Competence
9.	Designing and preparation of digital learning materials such as instructional videos or slides	2.94	2.8	2.87	0.52	Competence
10.	Ability to integrate multimedia (images, audio, video) into teaching materials	3.09	3.12	3.1	0.66	Competence
11.	Ability to develop online assessments (quizzes, assignments) for students	2.13	2.1	2.12	0.29	Low competence
12.	Creating and uploading content on e-learning platforms (e.g., Moodle, Google Classroom)	3.46	3.5	3.48	0.34	Competence
13.	Preparing digital models or simulations related to building construction concepts	3.27	3.12	3.2	0.27	Competence
14.	Encouraging collaborative learning through online platforms or forums	2.4	2.33	2.37	0.4	Low competence
15.	Participating in online professional development communities or webinars	2.35	2.2	2.28	0.42	Competence
16.	Provide students with feedback through digital platforms	2.36	2.82	2.59	0.37	Competence
17.	Use of digital tools to differentiate training based on student needs.	2.53	2.53	2.53	0.62	Competence
18.	Integrating digital tools to support student-centered and active learning	2.83	2.57	2.7	0.41	Competence
19.	Promoting safe and responsible use of technology among students	2.7	2.91	2.8	0.38	Competence
20.	Evaluating the effectiveness of digital tools used in teaching practices	2.51	2.2	2.36	0.49	Low competence
	Grand Average			2.71	0.47	Competence

Keys: N₁= Number of Head of Departments, N₂= Number of Lecturers, X₁ = Mean of Head of Departments, X₂ = Mean of Lecturers, X_T = Average Mean of head of Department and Lecturers, SD = Standard Deviation

The result in Table 2 revealed the mean ratings of the respondents on the level of lecturers' digital skills competence in the training of Building Technology students. The result revealed that item 1-5, 8-10, 12, 13, 15-19 have competence while item 6, 7, 11, 14 and 20 have low competence on the level of lecturers' digital skills competence in the training of Building Technology students. The grand average 2.17 show a modest level of digital-skills competence among lecturers involved in the training of Building Technology students. The result indicate that on average, lecturers demonstrate baseline capability in many digital tasks but are not uniformly strong across all areas.

Discussion

The results in research question one shows strong agreement on tools like CAD, LMS, and the internet reflects their established utility and relative affordability. These tools have become the digital backbone of building technology education, effectively supporting core competencies in design, information dissemination, and research (Almaian et al., 2023). The acceptance of project management software and BIM, albeit with moderate agreement, signals a positive trend towards incorporating industry-standard processes into the curriculum, which is crucial for graduate employability.

The most critical finding is the clear lag in adopting immersive and data-capture technologies like VR, AR, and drones. This discrepancy aligns with recent literature identifying key barriers to their implementation. The high initial cost of hardware and software, the steep learning curve for both staff and students, and the need for significant technical support are major impediments (Forcada et al., 2020). Furthermore, integrating these tools meaningfully into the curriculum requires a redesign of pedagogical approaches, moving beyond traditional lectures to more experiential, simulation-based learning, which can be time-consuming to develop.

However, the failure to adopt these tools creates a concerning "skills gap." The construction industry is rapidly digitizing, with VR being used for virtual mock-ups and safety training, AR for on-site assembly guidance and quality control, and drones for progress monitoring and surveying (Wang *et al.*, 2022). Graduates who have not been exposed to these technologies may find themselves at a disadvantage. The low utilization of architectural visualization tools (e.g., Lumion) is similarly problematic, as high-quality visual communication is a vital skill in a competitive AEC (Architecture, Engineering, and Construction) market. Effective BIM education goes beyond software operation; it requires teaching collaborative, multi-disciplinary workflows. A recent study emphasized that BIM's full benefits are only realized when it is taught as a process rather than just a tool, which many institutions still struggle with (Sacks & Gurevich, 2021).

The findings in research question two align with a growing body of research that distinguishes between basic digital literacy and the more complex concept of "digital pedagogical competence." The high scores on operational tasks (using PowerPoint, uploading to an LMS) are consistent with global trends showing that educators have become more proficient with core technologies, especially following the rapid digitalization necessitated by the COVID-19 pandemic (Scherer *et al.*, 2021). The ability to use field-specific software like digital models and simulations is particularly crucial in Building Technology, as it bridges theoretical knowledge and practical application, a point emphasized by studies in vocational education (Ghavifekr & Rosdy, 2015).

However, the identified areas of low competence are concerning and reflect a persistent gap in lecturers professional development. The inability to effectively search, select, and evaluate digital resources points to a deficit in information literacy within a digital context. In an era of information abundance, the skill to curate accurate, relevant, and high-quality resources for a specialized field like Building Technology is paramount. This goes beyond simple Google searches and requires critical evaluation of sources, much like the skills described in the European Framework for the Digital Competence of Educators (DigCompEdu) under the area of "Digital Resources" (Redecker, 2017).

Furthermore, the low ratings in developing online assessments and fostering online collaboration indicate a limited adoption of student-centered and constructivist learning approaches using technology. Modern digital pedagogy advocates for moving beyond the mere digitization of traditional lectures (e.g., slideshows) towards interactive learning where students co-create knowledge. The low score on evaluating the effectiveness of digital tools is perhaps the most systemic issue. It suggests a lack of reflective practice regarding technology use. Without this evaluative component, lecturers cannot know if a digital tool is genuinely enhancing learning or merely being used for its own sake. As noted by Instefjord and Munthe (2017), the mere provision of technology does not lead to improved learning outcomes; it is the pedagogically sound application and critical reflection on its use that makes the difference.

Conclusion and Recommendations

The study concludes that the current digital competency level of Building Technology lecturers is insufficient to fully prepare graduates for the modern construction industry. It recommends the implementation of pedagogically-focused professional development grounded in the TPACK framework, strategic investment in digital infrastructure, and the establishment of robust technical and peer-support systems to enhance the quality of digital skills integration in Building Technology education.

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AWARENESS AND USE OF ENERGY EFFICIENT MATERIALS FOR MITIGATING GLOBAL WARMING POTENTIALS IN RESIDENTIAL BUILDINGS IN MINNA, NIGER STATE

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Abstract

This study assesses the awareness and use of energy-efficient materials for mitigating Global Warming Potential (GWP) in residential buildings in Minna, Niger State, Nigeria. The study employs a descriptive survey research design, data was collected via a structured questionnaire from a census of 206 construction professionals (Builders, Engineers, and Architects) in nine registered firms in Minna. The data were analyzed using mean, standard deviation, and Analysis of Variance (ANOVA). The study found low awareness and practical knowledge level of energy-efficient, low-GWP construction materials among building professionals in Minna. While there was familiarity with some traditional, locally-sourced materials like bamboo and rammed earth, awareness of more advanced or processed sustainable materials. The study found that there was a significant challenge to the use of energy-efficient materials identified as their high initial cost compared to conventional alternatives. The study concludes that the mitigation of Global Warming Potential in Minna's residential building sector through energy-efficient materials is severely hampered by a combination of low professional awareness, significant economic constraints. The study recommends that government bodies, in collaboration with professional institutions (such as the Council of Registered Builders of Nigeria (CORBON), Nigerian Society of Engineers (NSE), and Nigerian Institute of Architects (NIA)), should develop and mandate continuous professional development workshops, seminars, and certification programs. These initiatives should focus on educating architects, engineers, and builders about the benefits, specifications, and application techniques of a wide range of energy-efficient materials, moving beyond traditional options to include modern, high-performance alternatives.

Keywords: Awareness, challenges, energy-efficient materials, global warming potential, residential buildings

Introduction

Residential buildings are structures specifically designed and constructed to provide shelter, security, and a comfortable living environment for human occupants, their belongings, and domestic animals (Ibrahim, 2025). Achieving this fundamental purpose requires the use of durable materials that ensure long-term structural stability and occupant comfort. As highlighted by Musa (2024), the selection of materials for residential construction is highly diverse, encompassing conventional options like blocks and concrete, bio-based materials such as timber, earthmud blocks, and bamboo, as well as engineered products like laminated boards and various roofing systems. Functionally, these buildings consist of sub-structural elements (foundations), super-structural components (walls, floors, roofs), and essential fittings and finishes, all working together to provide fundamental human comfort and protection from adverse weather conditions. The

materials chosen to create this shelter and comfort, however, have significant downstream implications for the broader environment, particularly concerning global warming.

The accelerating rate of global warming, driven predominantly by human-induced greenhouse gas (GHG) emissions, has placed a significant emphasis on the environmental impact of the built environment. Globally, buildings are responsible for approximately 36% of total energy consumption and nearly 39% of energy-related carbon dioxide emissions, underscoring the construction sector as a critical focal point for climate change mitigation efforts (International Energy Agency, 2021). This is a serious global issue with severe consequences for human health and ecosystems. The residential building sector contributes substantially to these GHG emissions, a trend amplified by rapid urbanisation and population growth. High energy consumption in residential buildings is frequently linked to inadequate insulation, inefficient design, and the use of energy-intensive materials. While building design and insulation are crucial for energy efficiency, the choice of construction materials fundamentally determines the embodied energy (energy consumed in extraction, manufacturing, and transport) and the operational energy required to maintain comfortable indoor conditions throughout the building's lifecycle (Bentall *et al.*, 2024). Consequently, the selection of building materials directly influences Global Warming Potential (GWP), as certain energy-efficient construction materials inherently possess higher embodied carbon and energy footprints than others (Ansah *et al.*, 2023).

Energy-efficient construction materials are specifically designed or selected to minimise energy consumption during the operation of a building. Examples include high-performance thermal insulation, reflective roofing systems, and advanced glazing technologies. When effectively incorporated, these materials can drastically reduce the operational energy demands of residential buildings for heating, cooling, and lighting (Abdullahi & Bawuro, 2020). Beyond operational savings, the inherent properties of certain materials contribute directly to lowering GWP, materials are increasingly categorised based on their environmental impact, including embodied energy, carbon emissions, and recyclability (Morini *et al.*, 2019). Sustainable materials like bamboo, rammed earth, cross-laminated timber (CLT), and recycled concrete offer considerable GWP reduction potential (Ezema *et al.*, 2015), often exhibiting lower embodied energy and carbon when compared to conventional materials like cement, steel, and brick (Ayodele *et al.*, 2020). Indigenous materials such as mud, laterite, and clay possess inherently low embodied energy and high thermal mass, enabling natural thermal regulation (Umar, 2022). Materials with high thermal mass (concrete) can stabilize indoor temperatures, reducing heating/cooling loads, while those requiring minimal processing energy (bamboo, rammed earth) further lower environmental impact. Awareness of renewable materials like timber actively sequester carbon during growth, helping offset emissions.

Awareness of energy-efficient materials entails understanding among key stakeholders – including homeowners, architects, builders, engineers and contractors regarding the availability, specific benefits (economic, environmental, comfort), and correct application methods for such materials.

This awareness is a critical antecedent to widespread adoption and significantly shapes behaviours and choices within the construction industry. However, significant gap exist, a survey in Nigeria revealed only 42% of architects were familiar with sustainable construction materials, and a mere 29% had actually applied them in projects, indicating a substantial knowledge deficit and lack of practical engagement (Umar, 2022). This limited awareness is particularly problematic given the relevance of locally available, energy-efficient options like compressed earth blocks, adobe, lime-based plasters, and insulation made from recycled glass, sheep wool, or plant fibers (Abdullahi & Bawuro, 2020). Sociocultural preferences also play a role; many homeowners and builders prioritise conventional materials and traditional aesthetics over performance, often due to limited exposure to the tangible advantages of energy-efficient alternatives (Ashibuogwu, 2024). This lack of awareness and preference for convention directly impacts the extent to which low-GWP materials are utilised in practice.

Statement of the Research Problem

Residential buildings, in particular owing to their sheer number and extensive use of high-embodied- carbon materials such as concrete, steel, and fired bricks, intensify GHG emissions. The construction industry stands among the most significant contributors to global warming potential (GWP), responsible for considerable greenhouse gas (GHG) emissions across every stage of a building's life cycle. By integrating energy efficient materials, it is possible to reduce embodied carbon, improve operational energy efficiency, and facilitate material recyclability. Yet in many regions of Nigeria, characterised by high humidity and elevated temperatures (Toriola-Coker *et al.*, 2021), the adoption and integration of such materials remain markedly low.

Despite increased awareness of climate change and its implications, the widespread use of energy efficient materials in Nigerian construction is thwarted by multiple, interrelated barriers. High upfront costs deter homeowners and developers from investing in alternative materials. Stakeholder knowledge gap among architects, contractors, and end- users limit informed decision- making about the benefits and applications of sustainable options. Moreover, the local market suffers from poor availability and underdeveloped production infrastructure, while technical expertise in installing and maintaining advanced materials is scarce (Ebekozi *et al.*, 2022). Inadequate policy frameworks, weak enforcement of building regulations, and a lack of financial incentives further exacerbate the problem, stalling progress toward greener construction practices.

Aim and Objectives of the Study

The aim of the study is to assess the awareness and use of energy efficient materials for mitigating global warming potentials in residential buildings in Minna, Niger State. The specific objectives of the study is to determine;

1. the energy efficient materials for mitigating global warming potential in residential buildings
2. the awareness of building professionals on energy efficient materials used in mitigating global warming potential in residential buildings

Research Questions

The following research questions were raised to guide the study;

1. What are the energy efficient materials in mitigating global warming potential in residential buildings?
2. What is the level of awareness of energy efficient materials used in mitigating global warming potential in residential buildings?

Hypotheses

The following hypotheses were formulated to guide the study and will be tested at 0.05 level of significance:

Ho₁: There is no significant difference on the mean responses of builders, architect and engineers with regards to the energy efficient materials used for mitigating global warming potential in residential buildings

Ho₂: There is no significant difference on the mean responses of builders, architect and engineers with regards to their awareness of energy efficient materials used in mitigating global warming potential in residential buildings

Literature Review

Theoretical Framework

Life cycle assessment (LCA) theory

Life cycle assessment (LCA) is a tool used to assess the potential environmental impacts and resources utilised throughout a product's life cycle (cradle to grave or cradle to gate), from raw material acquisition, via production, use phases, and waste management, to the recycling stage. It originated from Coca-Cola's study on beverage bottle selection in 1969 but did not gain widespread use until the late 1980s. The concept of LCA was proposed by the Society of Environmental Toxicology and Chemistry (SETAC) in 1990 and subsequently incorporated into the ISO 14000 Environmental Management Standards by the International Standard Organisation (ISO) in 1993. The ISO defined LCA as a method for compiling and evaluating the inputs, outputs, and potential environmental impacts of a product system throughout its life cycle. Currently, LCA is widely used in environmental management, industrial manufacturing, transportation, energy, and many other fields and has become an internationally recognized essential tool for environmental management, ecological design, and sustainable development. Life Cycle Assessment (LCA) is a systematic method used to evaluate the environmental impacts of building construction materials throughout their entire life cycle from extraction and manufacturing to transportation, usage, and disposal. In the context of mitigating global warming potential (GWP) in residential buildings, LCA provides a comprehensive approach to assessing and minimizing carbon emissions associated with material choices. Life Cycle Assessment (LCA) is a systematic method used to evaluate the environmental impacts of building construction materials throughout their entire life cycle from extraction and manufacturing to transportation, usage, and disposal. In the context of mitigating global warming potential (GWP) in residential

buildings, LCA provides a comprehensive approach to assessing and minimizing carbon emissions associated with material choices.

LCA helps in quantifying the carbon footprint of construction materials by analyzing various stages:

Raw Material Extraction: Evaluates the energy consumed and emissions released during extraction processes. Materials with high embodied energy, such as concrete and steel, are scrutinized for their environmental impact.

Manufacturing and Processing: Considers the energy requirements and greenhouse gas emissions during the manufacturing phase. Sustainable alternatives, like low-carbon cement or recycled steel, are assessed for their reduced GWP.

Transportation and Distribution: Analyses the emissions associated with transporting materials from production sites to construction locations. Locally sourced materials are often favored to minimise transportation-related carbon emissions.

Usage and Maintenance: Examines the energy efficiency and durability of materials throughout the building's lifespan. Materials that enhance insulation or require less maintenance contribute to lower operational emissions.

End-of-Life Disposal or Recycling: Assesses the environmental impact of demolition and disposal processes. Recyclable or biodegradable materials reduce landfill waste and GWP.

LCA enables architects, builders, and policymakers to make informed decisions on material selection that significantly reduce the overall carbon footprint of residential buildings. It encourages the utilisation of low-impact materials, such as bamboo, recycled wood, or geopolymers concrete, which offer lower embodied energy and higher carbon sequestration capabilities.

Global warming

The term global warming refers to changes that have occurred in the global climate since the 1900s and the ever increasing green house gas (GHG) emissions leading to the catastrophes associated to a changing climate (Singh, 2024). This has become a serious global environmental problem and is considered to be the most significant challenge facing global communities and therefore, making issues of global warming to be taken more seriously in recent times because of its devastating effects on the environment and its inhabitants (Abdulraheem *et al.*, 2022) The rate at which the climate has been changing since 1970s is alarming based on published statistical data which shows an average global temperature rise of 0.2°C and a 2 per cent rise in global precipitation (Chukwujama, 2021). The impact of global warming is felt in all areas of physical, ecological and social wellbeing, therefore, could presents potential challenges to future livelihoods (Lomborg, 2020)

Global warming is viewed as a problem that basically affects the environment in a significant way, thus, it has to be taken quite seriously. However, there are several arguments on the causes of climate change, which can be drilled down to four main strands (Reddy, 2021).

The first argument suggests that global warming is a natural phenomenon. Those in agreement argue that the earth's climate has changed several times in response to natural causes, these natural climatic changes are said to be a reflection of variability over certain time scales (Audi *et al.*, 2020). These natural causes include; interactions between oceans and the atmosphere, changes in the Earth's orbit patterns, microcosmic properties of the climate systems, frequencies in weather elements, increase in the degree of variability, and volcanic eruptions of gases which absorb energy that are radiated from the earth's surface (Adak *et al.*, 2023).

The trapped or absorbed energy concentration in the atmosphere warms the atmosphere and in turn increases the earth surface temperatures globally, as shown in Figure 2.2. Therefore, the persistent shift in the mean state of natural climate or in its variability refers to Global warming (Amoo & Fagbenle, 2020). Hence, these arguments support the view that global warming occurs naturally. If this view holds, actions currently taken to reverse global warming effects are not only superfluous but likely to distort the patterns of the natural environment.

Building construction materials used in mitigating global warming potential

The construction industry is a significant contributor to global greenhouse gas emissions, primarily due to the embodied energy of building materials and operational energy use in buildings. In response to increasing concerns about global warming, sustainable and low-carbon building materials have gained attention for their potential to mitigate global warming potential (GWP) in residential buildings. Low-carbon building materials are designed to minimise embodied carbon emissions by using alternative raw materials, energy efficient manufacturing processes, and recycling strategies. Research highlights the benefits of utilizing agro-waste products, which are both abundant and renewable, as sustainable building materials. Agro-waste materials, such as rice husk ash, sugarcane bagasse ash, and bamboo leaves ash, have been effectively used in producing bricks, green concrete, insulation materials, and bio-based plastics, thereby reducing the reliance on conventional high-emission materials (Bhattacharyya *et al.*, 2021). Energy efficient building materials are essential for reducing operational energy use in residential buildings. Lightweight plasters containing vermiculite and FGD gypsum have been identified as sustainable and energy efficient solutions due to their insulating properties and low embodied energy (Abdullahi *et al.*, 2019). Additionally, using agro-waste groundnut shells and their derivatives has shown potential as energy efficient building materials, promoting sustainability and minimizing carbon emissions (Fakana, 2020).

Research Methodology

A descriptive survey research was adopted for the study. The study was conducted in Minna Metropolis. The population for this study is two hundred and six (206) professionals which consists

of seventy-eight (78) builders, forty-four (44) architects, and eighty-four (84) engineers in nine registered building construction companies operating in Minna. This study employ a census approach, collecting data from all members of the target population rather than using a sample. The data collected will be organise in line with the research question and hypotheses formulated for the study. Statistical Package for the Social Sciences (SPSS Version 23) will be used for analyse data. Mean and standard deviation will be used to answer the research questions, while Analysis of variance (ANOVA) statistics will be used to test the null hypothesis at 0.05 level of significance.

Results

Researched Question One

What are the energy efficient materials used in mitigating global warming potential in residential buildings?

The answer to research question one is presented in Table 1

Table 1: Mean Rating of the Respondents on Energy Efficient Materials Used in Mitigating Global Warming Potential in Residential Buildings

S/N	ITEMS	X ₁ N=78	X ₂ N=84	X ₃ N=44	X _T	SD	Remarks
1.	Bamboo	3.11	3.39	3.07	3.19	0.14	Agreed
2.	Hempcrete	2.46	2.15	2.73	2.45	0.24	Disagreed
3.	Cross-Laminated Timber (CLT)	2.36	2.37	2.58	2.44	0.1	Disagreed
4.	Rammed earth	2.88	2.71	3.36	2.98	0.28	Agreed
5.	Straw Bale	3.15	3.14	3.55	3.28	0.19	Agreed
6.	Recycled Aggregate Concrete (RAC)	2.68	2.03	2.95	2.55	0.39	Agreed
7.	Fly Ash Concrete	3.57	3.18	3.29	3.35	0.16	Agreed
8.	Recycled Steel	3.1	2.98	3.29	3.12	0.13	Agreed
9.	Recycled plastic bricks	2.77	3.05	2.81	2.88	0.12	Agreed
10.	Glasscrete	2.63	2.64	2.18	2.48	0.21	Disagreed
11.	Cellulose insulation	2.55	2.6	2.93	2.69	0.17	Agreed
12.	Sheep Wool Insulation	3.17	3.39	3.36	3.31	0.1	Agreed
13.	Phase-Change Materials (PCMs)	2.7	2.53	2.66	2.63	0.07	Agreed
14.	Cool Roofing Materials	2.1	2.22	2	2.11	0.09	Disagreed
15.	Carbon-Negative Cement	2.64	2.49	2.23	2.45	0.17	Disagreed
16.	Mycelium-Based Bricks	3.18	2.8	3.19	3.06	0.18	Agreed
17.	Low-carbon concrete	2.29	2.24	2.38	2.3	0.06	Disagreed
18.	Recycled denim	2.28	2.47	2	2.25	0.19	Disagreed
19.	Dimensional stone	2.85	2.98	3.15	2.99	0.12	Agreed
20.	Low-VOC paints	2.85	2.9	2.47	2.74	0.19	Agreed
21.	Cork wood	3.02	3.6	2.33	2.98	0.52	Agreed
22.	Energy efficient glazing	3.36	3.51	3.6	3.49	0.1	Agreed
23.	Geopolymer concrete	3.16	3.45	2.99	3.2	0.19	Agreed
24.	Aerogels	2.98	3.59	2.89	3.15	0.31	Agreed
25.	Advanced polystyrene	3.16	2.89	2.86	2.97	0.13	Agreed

26. Carbon-smart finishing materials	2.52	2.31	2	2.28	0.21	Disagreed
27. Solar reflective roofing or cool roof coatings	2.58	3.07	2.91	2.85	0.2	Agreed
28. Reflective shingle and tiles	2.37	2.22	2.11	2.23	0.11	Disagreed
Grand Average				2.8	0.18	Agreed

Keys: N₁= Number of Builders, N₂= Number of Architects, N₃= Number of Engineer, X₁ = Mean of Builders, X₂ = Mean of Architects, X₃ = Mean of Engineers, X_T = Average Mean of the Respondents, SD = Standard Deviation

The results in Table 1 shows the energy efficient materials used in mitigating global warming potential in residential buildings. The result reveal that several materials agreed with energy efficient glazing led the list with a mean score of 3.49, followed closely by Fly Ash Concrete (3.35) and Sheep Wool Insulation (3.31). Other highly-regarded materials included Straw Bale (3.28) and Geopolymer concrete (3.20). This indicate that these materials are well-understood and trusted by the building professionals for their role in reducing the environmental impact of residential construction. Also some materials were rated poorly which Disagreed such as cool roofing materials which received the lowest overall rating at 2.11, followed by reflective shingle and tiles (2.23), low-carbon concrete (2.30), and carbon-smart finishing materials (2.28). This indicate that, respondents disagreed on their effectiveness of the energy efficient materials used in mitigating global warming potential in residential buildings. The standard deviation (SD) reveal that most materials showed a reasonable agreement between the building professionals. For instance, Cork wood had a very high SD of 0.52, recycled aggregate concrete (RAC) had an SD of 0.39. The result revealed that there was positive perception of the effectiveness of various energy-efficient materials in mitigating global warming potential in residential buildings. The grand average mean rating of 2.80, with a remark of "Agreed," indicates that, on the whole, respondents believe these materials are beneficial.

Research Question Two

What is the awareness of energy efficient materials used in mitigating global warming potential in residential buildings?

The answer to research question two is presented in Table 2

Table 2: Mean Rating of the Respondents on Awareness of Energy Efficient Materials used in Mitigating Global Warming Potential in Residential Buildings

S/N	ITEMS	X ₁ N=78	X ₂ N=84	X ₃ N=44	X _T	SD	Remarks
1.	Low-embodied-carbon concrete alternatives (geopolymer, fly-ash concrete)	2.22	2.16	2.17	2.18	0.03	Not aware
2.	High-performance insulation materials that reduce heating/cooling loads	3.42	3.55	3.6	3.52	0.08	Aware
3.	Recycled-content steel products used in framing and reinforcements	3.49	3.6	3.49	3.53	0.05	Aware
4.	Heard of cross-laminated timber (CLT) or engineered wood as a low-GWP structural material	2.71	2.41	2.7	2.61	0.14	Aware

5.	Photovoltaic roofing tiles for on-site renewable energy	2.62	2.62	2.91	2.72	0.14	Aware
6.	Recognition on the role of high-albedo exterior coatings in reducing heat absorption	2.41	2.49	2.27	2.39	0.09	Not aware
7.	Phase-change materials (PCMs) for passive thermal regulation in walls	3.05	3.04	3.27	3.12	0.11	Aware
8.	Low-VOC (volatile organic compound) materials can improve both indoor air quality and GWP	2.79	2.81	2.57	2.72	0.11	Aware
9.	Familiarity with cool-roof membranes designed to reflect more solar radiation	3.54	3.24	3.45	3.41	0.13	Aware
10.	Have you heard about bio-based insulation (e.g., sheep's wool, cellulose) as sustainable options	3.28	3.3	3.6	3.39	0.15	Aware
11.	Awareness on locally sourced materials can lower transportation-related carbon emissions	2.73	2.73	2.83	2.76	0.05	Aware
12.	Recognition on the environmental benefits of using reclaimed or salvaged building components	3.28	3.35	3.13	3.25	0.09	Aware
13.	Familiarity with low-GWP cement substitutes like limestone calcined clay cement (LC ³)	2.07	2.01	2	2.03	0.03	Not aware
14.	Are you aware that high-efficiency glazing systems (double/triple pane) can reduce energy demand	3.23	2.78	2.73	2.91	0.22	Aware
15.	Awareness of of aerogel blankets as ultra-thin, high-insulating building materials	2.01	2.04	2	2.02	0.02	Not aware
16.	Permeable paving materials can reduce urban heat island effects	2.47	2.49	2.14	2.37	0.16	Not aware
17.	Awareness on carbon-sequestration potential of hempcrete and other bio-composites	2.98	3.15	3.43	3.19	0.19	Aware
Grand Average					2.83	0.11	Aware

Keys: N₁= Number of Builders, N₂= Number of Architects, N₃= Number of Engineer, X₁ = Mean of Builders, X₂ = Mean of Architects, X₃ = Mean of Engineers, X_T = Average Mean of the Respondents, SD = Standard Deviation

The result in Table 2 shows the awareness of energy efficient materials used in mitigating global warming potential in residential buildings. The result reveals that several items show relatively strong awareness across groups which are high-performance insulation (Item 2, X = 3.52, SD = 0.08), recycled-content steel (Item 3, X = 3.53, SD = 0.05), cool-roof membranes (Item 9, X = 3.41, SD = 0.13), bio-based insulation such as sheep's wool or cellulose (Item 10, X = 3.39, SD = 0.15), phase-change materials (Item 7, X = 3.12, SD = 0.11), and recognition of reclaimed or salvaged components (Item 12, X_T = 3.25, SD = 0.09) all score above the awareness threshold. The low SD values for many of these items indicate consistent recognition among the three professions. These findings point to widespread appreciation of established, market-available solutions particularly insulation technologies, cool roofing, and recycled structural products that have clearer performance evidence and adoption pathways.

The result also reveal some items which shows low average ratings and are flagged as “Not aware.” These include low-embodied-carbon concrete alternatives (Item 1, $X = 2.18$, $SD = 0.03$), high-albedo exterior coatings (Item 6, $X = 2.39$, $SD = 0.09$), low-GWP cement substitutes such as LC (Item 13, $X = 2.03$, $SD = 0.03$), aerogel blankets (Item 15, $X = 2.02$, $SD = 0.02$), and permeable paving materials (Item 16, $XT = 2.37$, $SD = 0.16$). The very small SDs on some of these (Items 1, 13, 15) suggest a uniformly low level of awareness. These low scores likely reflect lesser market penetration, higher perceived cost, limited local supply chains, or lack of exposure in professional training.

The result indicate a generally positive level of awareness about a range of energy-efficient materials and strategies. The grand average mean rating across the 17 items is $XT = 2.83$ ($SD = 0.11$), which the study regarded as “Aware.” This implies that, collectively, the professional groups have good familiarity with many low-GWP materials and technologies relevant to mitigating residential building greenhouse-gas impacts.

Hypothesis one

H₀₁: There is no significant difference on the mean responses of builders, architect and engineers with regards to the energy efficient materials used for mitigating global warming potential in residential buildings

The result is presented in Table 3

Table 3: ANOVA Analysis on the Mean Responses of Builders, Architect and Engineers with regards to the Energy Efficient Materials used for Mitigating Global Warming Potential in Residential Buildings

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	10.3067	2	1.50	96.80	0.001
Within Groups	5.1533	203	0.074		
Total	15.46	205			

The ANOVA result in Table 3 revealed the mean responses of builders, architect and engineers with regards to the energy efficient materials used for mitigating global warming potential in residential buildings. The result showed that $F = 96.80$, $p < 0.001$ (Between-groups $SS = 10.3067$, $df = 2$; Within-groups $SS = 5.1533$, $df = 203$; Total $SS = 15.46$, $df = 205$). The p-value is well below the conventional 0.05 threshold, therefore there was a significant difference in the mean responses of builders, architect and engineers with regards to the energy efficient materials used for mitigating global warming potential in residential buildings

H₀₂: There is no significant difference on the mean responses of builders, architect and engineers with regards to their awareness of energy efficient materials used in mitigating global warming potential in residential buildings.

Table 4: ANOVA Analysis on the Mean Responses of Builders, Architect and Engineers with Regards to their Awareness of Energy Efficient Materials used in Mitigating Global Warming Potential in Residential Buildings

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.73	2	1.19	40.53	0.001
Within Groups	2.37	203	0.059		
Total	7.10	205			

The ANOVA result in Table 4 revealed the mean responses of builders, architect and engineers with regards to their awareness of energy efficient materials used in mitigating global warming potential in residential buildings. The result showed that $F = 40.53$, $p < 0.001$ (Between-groups $SS = 4.73$, $df = 2$; Within-groups $SS = 2.37$, $df = 203$; Total $SS = 7.10$, $df = 205$). The p-value is well below the conventional 0.05 threshold, therefore there was a significant difference in the mean responses of responses of builders, architect and engineers with regards to their awareness of energy efficient materials used in mitigating global warming potential in residential buildings.

Discussion

The findings on research question one reveal that perceived effectiveness of energy-efficient materials for mitigating the global warming potential (GWP) of residential buildings. The strong performance of Energy-Efficient Glazing (Mean=3.49) is well-justified, as it directly targets a building's largest source of energy loss: the envelope. Advanced glazing systems, such as double or triple-pane windows with low-emissivity coatings and argon gas fills, significantly reduce heat transfer, thereby lowering the demand for space heating and cooling, which are primary contributors to operational carbon emissions (International Energy Agency, 2022). This high rating indicates that professionals recognize the critical role of reducing operational energy, a domain where high-performance windows have a proven and immediate impact.

Following closely, Fly Ash Concrete (Mean=3.35) and Geopolymer Concrete (Mean=3.20) represent a growing professional trust in innovative, low-embodied carbon materials. Traditional Portland cement production is notoriously carbon-intensive, accounting for approximately 8% of global CO₂ emissions (Monteiro *et al.*, 2017). Both fly ash concrete, which uses a industrial by-product to replace a portion of cement, and geopolymer concrete, which entirely avoids Portland cement by using an alkaline activator, offer substantial reductions in embodied carbon. Their high mean scores suggest that the construction industry is increasingly aware of and values strategies that address the "upfront" carbon footprint of building materials, moving beyond a sole focus on operational energy (Marsh *et al.*, 2022). Similarly, bio-based materials like Sheep Wool Insulation (Mean=3.31) and Straw Bale (Mean=3.28) are perceived favorably, likely due to their renewable nature, excellent thermal performance, and ability to sequester carbon during their growth phase (Pal *et al.*, 2021).

Conversely, the low ratings for Cool Roofing Materials (Mean=2.11) and Reflective Shingles and Tiles (Mean=2.23) are particularly striking and warrant further investigation. This "disagreement" may stem from a geographical or climatic bias among the respondents. While cool roofs, which reflect sunlight and emit heat, are exceptionally effective at reducing cooling loads and mitigating the urban heat island effect in hot climates, their benefits can be negated in colder regions where they may increase winter heating demand (Sailor et al., 2021). This suggests a potential gap in context-specific knowledge or a respondent pool from predominantly temperate or cold climates. The similarly low scores for Low-Carbon Concrete (Mean=2.30) and Carbon-Smart Finishing Materials (Mean=2.28) might indicate skepticism about the real-world performance, durability, or cost-effectiveness of these newer, less proven technologies compared to established alternatives like fly ash concrete.

The results from Table 2 reveal a distinct stratification in professional awareness of energy-efficient materials, highlighting a clear preference for established, performance-proven technologies over emerging alternatives. The high awareness scores for high-performance insulation ($X = 3.52$), cool-roof membranes ($X = 3.41$), and bio-based insulation ($X = 3.39$) underscore a strong market and professional consensus on the critical role of the building envelope in operational energy efficiency. This aligns with recent literature, which consistently identifies superior insulation and solar-reflective roofing as foundational strategies for reducing operational carbon, the dominant source of a building's lifetime energy use (Attia et al., 2020). Similarly, the recognition of recycled-content steel ($X = 3.53$) points to a matured understanding of circular economy principles within the construction sector. The high awareness of these items, coupled with their low standard deviations, suggests that knowledge has successfully permeated across the professions of architects, engineers, and contractors, likely driven by established certification systems like LEED and BREEAM that have long incentivized such materials.

Conversely, the data exposes a significant awareness gap concerning materials targeting the upfront, or embodied, carbon of buildings—a frontier in sustainable construction. The items flagged with the lowest awareness, including low-embodied-carbon concrete alternatives ($X = 2.18$) and low-GWP cement substitutes ($X = 2.03$), are particularly telling. Concrete and cement production are responsible for approximately 8% of global CO₂ emissions (Monteiro et al., 2023), making this a critical area for mitigation. The uniformly low scores and minimal standard deviations for these items indicate a systemic, rather than isolated, knowledge deficit. This lag can be attributed to several factors: these materials are often newer to the market, face perceived risks regarding structural performance and durability, and suffer from underdeveloped supply chains (Miller et al., 2021). The very low awareness of aerogel blankets ($X = 2.02$), despite their superior insulating properties, further illustrates how high cost and niche application can limit professional familiarity.

The overall grand mean ($XT = 2.83$), which the study categorizes as "Aware," presents an encouraging yet nuanced picture. It suggests that the collective professional community possesses

a solid foundational knowledge of the material palette available for reducing the Global Warming Potential (GWP) of residential buildings. This foundational awareness is a necessary first step for market transformation. However, the concentration of high awareness in operational energy savings strategies, contrasted with the poor awareness of embodied carbon solutions, indicates that the industry's focus may still be lagging behind the latest climate priorities. As the operational efficiency of buildings improves, the proportional share of embodied carbon in the building lifecycle increases significantly, making it the next critical battleground for decarbonization (Röck *et al.*, 2020). Therefore, while the result is generally positive, it also serves as a clear call to action for targeted education, policy incentives, and industry-wide collaboration to bridge the critical knowledge gap in low-embodied-carbon materials if ambitious climate goals are to be met.

The hypothesis one revealed that highly significant ANOVA result ($F = 96.80$, $p < .001$) unequivocally demonstrates a statistically significant divergence in the perceptions of builders, architects, and engineers regarding the use of energy-efficient materials for mitigating the global warming potential (GWP) of residential buildings. With a p-value far below the conventional alpha level of .05, the null hypothesis that there are no differences in the mean responses across these three professional groups can be confidently rejected. The substantial F-statistic, driven by a between-groups sum of squares (10.31) that is double the within-groups sum of squares (5.15), indicates that the variation attributable to professional discipline is significantly greater than the variation within each group. This finding is critical, as it moves beyond simply acknowledging that energy-efficient materials are important and instead reveals that the professional lens through which these materials are viewed is not uniform.

This lack of consensus can be largely attributed to the distinct roles, priorities, and educational backgrounds inherent to each profession. Engineers, grounded in quantitative performance metrics and life-cycle assessment (LCA) methodologies, likely prioritize materials with demonstrably low embodied carbon and high operational efficiency, such as cellulose insulation or low-carbon concrete mixes (Schwartz *et al.*, 2023). Architects, while concerned with performance, often balance these demands with aesthetic, spatial, and experiential qualities. Their responses may be influenced by a material's visual appeal, integration with design intent, and the ability to meet client expectations for sustainability, which can sometimes favor newer, more visually prominent materials like structural insulated panels (SIPs) or cross-laminated timber (CLT), even if their full LCA is complex (Kylili & Fokaides, 2020). Builders, or contractors, operate with a primary focus on practicality, cost, supply chain reliability, and labor proficiency. Their perspective on an "energy-efficient material" is likely filtered through the lens of installability, durability, local availability, and short-term economic cost, potentially making them more cautious about adopting novel materials with which their workforce is unfamiliar, even if they offer superior environmental credentials (Attia *et al.*, 2022).

The practical implication of this significant disparity is profound. The successful integration of energy-efficient materials into residential buildings is a deeply collaborative process. If architects

specify materials that builders find difficult or costly to install, or if engineers recommend solutions that clash with the architectural design, the result can be value engineering that removes the sustainable elements, delays, cost overruns, and ultimately, a building that fails to achieve its intended GWP mitigation. This "performance gap" between design intent and as-built reality is a well-documented challenge in sustainable construction, and this ANOVA result provides quantitative evidence that divergent professional perceptions are a key contributor to this problem (Attia *et al.*, 2022). Therefore, the finding is not merely a statistical observation but a call to action for the industry. It underscores the urgent need for interdisciplinary education, early collaboration in the integrated design process, and the development of common frameworks and tools that can translate the priorities of one discipline into the operational language of another, thereby aligning the disparate mean responses towards the shared goal of meaningful climate change mitigation in the built environment.

The hypothesis two reveal a statistically compelling evidence that the level of awareness regarding energy-efficient materials and their role in mitigating the global warming potential (GWP) of residential buildings is significant. With a substantial F-statistic of 40.53 and a p-value of less than 0.001, the null hypothesis—that no difference exists between the mean awareness levels of builders, architects, and engineers—is decisively rejected. The high F-value, derived from a between-groups sum of squares (4.73) that is double the within-groups sum of squares (2.37), indicates that the variation in responses between the professional groups is significantly greater than the variation within each group. This confirms that professional discipline is a major factor influencing awareness, rather than the difference being due to random chance or individual discrepancies within the professions.

This significant disparity aligns with recent research that highlights the fragmented nature of knowledge and priorities within the Architecture, Engineering, and Construction (AEC) sector. For instance, a study by Kyllil *et al.* (2021) found that architects often lead in specifying materials with low embodied carbon due to their focus on environmental product declarations and life-cycle assessment tools integrated into Building Information Modeling (BIM). In contrast, builders or contractors may prioritize materials based on short-term costs, availability, and familiar construction methods, which can create a gap between design intent and actual building performance. This "performance gap" is a well-documented challenge, where the theoretical energy efficiency of a design is not realized in the constructed building, partly due to a misalignment of knowledge and objectives among stakeholders (De Wilde, 2019).

The root of this divergence can be traced to differing educational backgrounds, professional responsibilities, and exposure to sustainability mandates. Engineers, particularly structural and civil engineers, are increasingly trained to calculate and minimize the embodied carbon of building structures, making them highly aware of material choices like low-carbon concrete or recycled steel (Monteiro *et al.*, 2022). Builders, however, operate under different pressures; their awareness is often shaped by on-the-ground practicality, client budgets, and local building codes rather than

advanced sustainability metrics. Therefore, the significant F-value in this ANOVA underscores a critical bottleneck in the holistic adoption of sustainable construction: without a concerted effort to align the awareness and priorities of all three groups, the industry's ability to effectively mitigate the GWP of the built environment will remain hampered.

Conclusion and Recommendations

In conclusion, this study reveals there is a foundational level of awareness and a positive perception of the utility of certain energy-efficient materials for mitigating Global Warming Potential (GWP), this awareness is markedly stratified and incomplete. The significantly low overall awareness levels, particularly concerning advanced and low-embodied carbon materials like geopolymers concrete and aerogels, severely hinder their adoption. Furthermore, the highly significant ANOVA results ($p < 0.001$) for both the use and awareness of these materials indicate a profound divergence in the knowledge, priorities, and perceptions among builders, architects, and engineers. This professional fragmentation, compounded by the predominant barrier of high initial cost, creates a formidable obstacle to the integrated design and delivery of sustainable buildings. Therefore, the mitigation of GWP in Minna's residential building sector is critically hampered not by a singular issue, but by a synergistic combination of generally low professional awareness, significant economic constraints, and a lack of aligned perspectives across the key disciplines responsible for building conception and construction.

Recommendations

It is recommended that professional bodies, including the Nigerian Institute of Architects (NIA), Nigerian Society of Engineers (NSE), and Council of Registered Builders of Nigeria (CORBON), in collaboration with academic institutions, develop and mandate continuous professional development programs. These initiatives must move beyond generic sustainability concepts to provide targeted, interdisciplinary education on the technical specifications, life-cycle cost benefits, and practical application techniques of a wide range of energy-efficient materials, with a special emphasis on locally-sourced and low-embodied carbon alternatives.

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PRIVACY-CENTRIC SELF-SOVEREIGN IDENTITY FRAMEWORK DESIGN FOR PUBLIC BLOCKCHAINS

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Abstract

Identity management has evolved over time, yet centralized and federated models remain vulnerable to large-scale data breaches and privacy concern. This paper presented a privacy-centric Self-Sovereign Identity (SSI) framework for public blockchains that incorporates advanced cryptographic method, such as ephemeral Decentralized Identifiers (DIDs), BBS+ selective disclosure signatures, and accumulator-based revocation. The framework was designed and evaluated using a Design Science Research (DSR) methodology, it encompassing architectural design, prototype implementation, and performance testing on the Ethereum testnet. With a slight performance overhead of 10–15% in latency and throughput, experimental results show an 80% reduction in linkability risk when compared to baseline SSI models. These results demonstrate that blockchain-based identity systems can successfully balance privacy, scalability, and usability. The study contributes a deployable, empirically validated architecture that advances privacy-by-design principles for next-generation digital identity infrastructures.

Keywords: Self-Sovereign Identity (SSI), Blockchain, Privacy, Verifiable Credentials, Decentralized Identifiers

Introduction

Identity management has undergone a transformation from physical documents to centralized and federated digital systems (Buchler, 2023). While federated identity solutions, such as Google or Facebook logins, provide convenience, they also concentrate sensitive personal data in centralized repositories, making them prime targets for cyber attacks. The severity of this threat is exemplified by the 2017 Equifax intrusion, which compromised the personal information of 147 million individuals (Berghel, 2017). Such flaws erode user confidence and endanger personal privacy, business integrity, and national security (Bhattacharya *et al.*, 2020).

Self-Sovereign Identity (SSI) is a paradigm that allows individuals to take ownership of their digital identities from third-party providers (Mühle *et al.*, 2018). By employing blockchain technology, SSI allows users to manage and deliver verifiable credentials without the need for middlemen (Bandara *et al.*, 2021). However, the transparency of public blockchains poses new privacy problems, as transaction patterns can be studied to identify users (Pava-Díaz *et al.*, 2024). Existing SSI solutions frequently struggle to balance verifiability and privacy, leaving a significant research vacuum (Shuaib *et al.*, 2022).

This paper proposes and evaluates a privacy-centric SSI framework that incorporates advanced cryptographic techniques to address the identified challenges. The primary objective is to design a system that provides users with data sovereignty while satisfying the performance requirements of contemporary digital economies. The specific objectives are to design a multi-layered, privacy-

by-design SSI framework, implement a prototype, and evaluate its performance and privacy guarantees relative to a baseline model.

Related Work

Traditional, federated, and decentralized systems are the three primary phases of identity management's development. Conventional systems used tangible, falsifiable documents. Federated identity, which was introduced by the internet era and allows services like Google and Facebook to authenticate users across platforms, has led to centralized points of failure and serious privacy issues (Aldosary & Alqahtani, 2021).

Decentralised identity, powered by blockchain, emerged to eliminate central authorities, enhancing security and user autonomy (Loffi *et al.*, 2025). SSI represents the maturation of this trend, giving individuals full ownership of their digital identities through three core components (Mulaji & Roodt, 2022):

Decentralised Identifiers (DIDs): User-controlled, globally unique identifiers that are not dependent on a central registry, as specified by the W3C (2022).

Verifiable Credentials (VCs): Tamper-evident, digitally signed claims issued by a trusted entity that a user can present to a verifier without the issuer's direct involvement (W3C, 2025).

Digital Wallets: Secure software applications where users store their DIDs and VCs, manage cryptographic keys, and control the selective disclosure of their information (Mulaji & Roodt, 2022).

Blockchain offers SSI a trust anchor, but because it is public, there are privacy concerns (Nokhbeh *et al.*, 2021). Adversaries may be able to correlate user activity by posting DIDs or credential proofs on-chain (Samovar & Samovar, 2025). Privacy-Enhancing Technologies (PETs) are essential to reducing this. A user can prove a claim using Zero-Knowledge Proofs (ZKPs) without disclosing the supporting information (Schardong & Custódio, 2022). More sophisticated signature schemes, such as BBS+, are made especially for SSI and allow a holder to generate unlinkable proofs that reveal only a portion of a credential's attributes (Tessaro & Zhu, 2023).

Current SSI systems, such as Microsoft ION (Dingle, 2020), uPort (Panait *et al.*, 2020), and Sovrin (Kassem *et al.*, 2019), have made important contributions, but they have drawbacks because of their scalability, centralization, or insufficient privacy protections. A dearth of empirically validated frameworks that integrate multiple PETs and assess their practical performance on public blockchains is evident in the numerous studies that have suggested theoretical privacy enhancements (Čučko & Turkanović, 2021). By creating and evaluating a comprehensive SSI framework on Ethereum, this study fills that gap.

Methodology

The suggested privacy-centric SSI framework is the technical artifact of the Design Science Research (DSR) approach, which is centered on its development and assessment. Problem identification, framework design, prototype implementation, and thorough evaluation were all done iteratively in this methodology. A tiered architecture is used in the design of the suggested

framework to guarantee adaptability and modularity. As seen in Figure 1, it is composed of four separate layers.

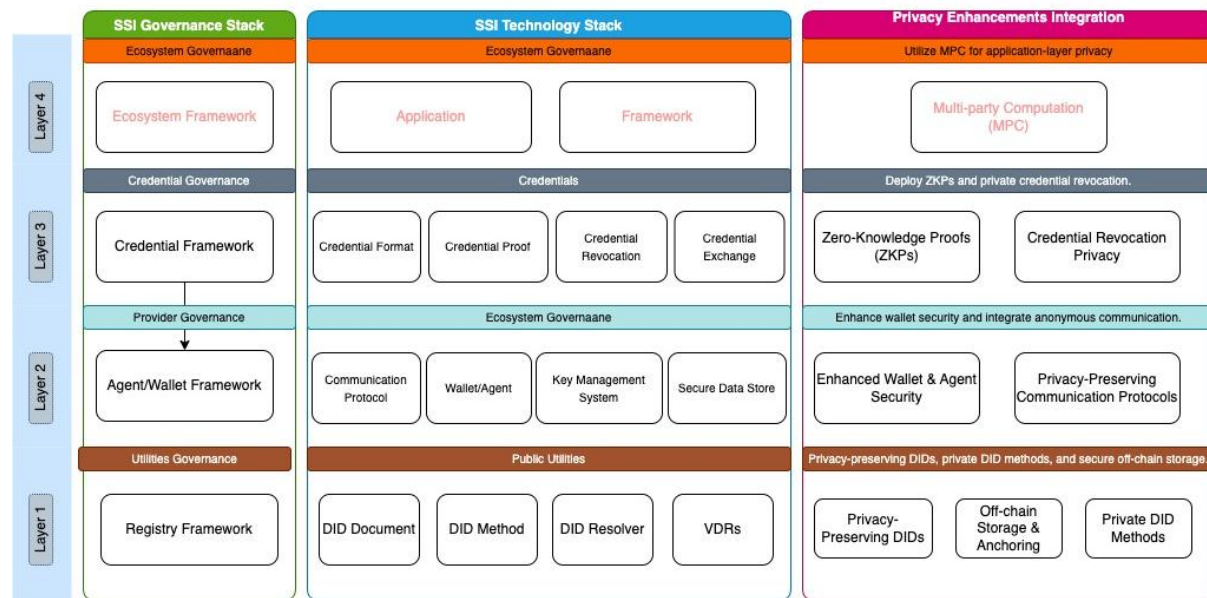


Figure 1: The Four-Layer SSI Framework Architecture

- i. **Utilities Layer:** Utilities Layer: The fundamental cryptographic primitives are provided by this layer. In order to avoid long-term tracking and correlation, it introduces ephemeral DIDs, which are transient identifiers created for individual interaction sessions. To reduce data exposure, only a hash commitment is anchored rather than the entire DID being placed on-chain.
- ii. **Provider Layer:** This layer enables private and secure communication between identity actors (issuers, holders, and verifiers). By using the DIDComm v2 protocol and onion routing techniques, it obscures metadata, making it impossible for traffic analysis to link communicating parties.
- iii. **Credential Layer:** The entire lifecycle of verifiable credentials is managed by this layer. Strong selective disclosure is made possible by the use of BBS+ signatures when issuing credentials. A user can use a credential to show certain attributes, like their employment status, without revealing other personal information, such as their employee ID number or start date. By using cryptographic accumulators for revocation, the framework allows a user to prove that their credential has not been revoked without revealing the credential's identity on a public list.
- iv. **Ecosystem Governance Layer:** This uppermost layer makes sure the framework complies with legal and regulatory mandates, including eIDAS 2.0 and GDPR. Using smart contracts to transparently enforce policies, it establishes the guidelines for auditability, consent, and trust within the ecosystem.

Solidity was used for smart contracts and Node.js for wallet applications in the implementation of a prototype of this framework on the Ethereum Goerli testnet. The Hyperledger Ursa library handled cryptographic operations. Performance, privacy, and scalability were assessed using a combination of network analysis tools (Wireshark), load testing software (JMeter, Locust), and blockchain monitoring tools (Etherscan).

Results and Discussion

The framework was evaluated against a baseline SSI model that uses static DIDs and does not include advanced PETs. The evaluation focused on system performance, privacy guarantees, and scalability.

System Performance

Under increasing concurrent request loads, throughput (verifications per second) and latency (end-to-end verification time) were measured. The suggested framework added a slight latency overhead of roughly 14–25% over the baseline, as indicated in Table 1. The computational expense of checking revocation accumulators and producing selective disclosure proofs is the reason for this.

Table 1: Latency Comparison between Baseline and Proposed SSI Framework

Concurrent Requests	Baseline SSI (ms)	Proposed Framework (ms)	Overhead (%)
10	120	145	+20.8%
50	248	310	+25.0%
100	325	392	+20.6%
300	540	620	+14.8%
500	730	835	+14.4%

The framework's peak throughput was about 11–14% lower than the baseline, with 115 transactions per second compared to 130 transactions per second. Despite this performance trade-off, the overhead stays constant and does not increase under increased loads, demonstrating the architecture's durability. The performance remains within reasonable bounds for real-world applications where enhanced privacy is an essential requirement.

Privacy and Scalability

The primary goal was enhance privacy. By mimicking an adversary's attempt to connect a user's interactions across sessions, the risk of privacy leakage was assessed. The findings were unmistakable: the adversary's linkability success rate was lowered by 80% from 61% in the baseline model to just 12% in the suggested framework by combining randomized BBS+ proofs, onion routing, and ephemeral DIDs. The selective disclosure mechanism was also quite successful on average, individuals were only able to disclose 6–22% of the required features of their credentials, as opposed to 100% in the baseline.

Scalability tests of the framework's scalability revealed that its performance increases linearly with the number of validator nodes and gradually declines when the number of concurrent users rises into the thousands. It is confirmed that the privacy improvements do not result in a scaling bottleneck because the performance overhead relative to the baseline stayed constant at about 10-15%.

Conclusion and Recommendations

This research successfully designed, implemented, and evaluated a privacy-centric SSI framework on a public blockchain. The study concludes that the integration of ephemeral DIDs, BBS+ selective disclosure, and cryptographic accumulators provides a robust solution to the privacy challenges inherent in blockchain-based identity systems. The experimental evidence validates that this approach substantially reduces the risk of user activity correlation and minimizes data exposure, achieving these gains with an acceptable and stable performance trade-off. The framework proved to be both scalable and secure, making it a viable solution for real-world deployment in sensitive domains such as national security and enterprise environments.

Based on these findings, the following recommendations are made:

1. **For Developers:** Prioritize the adoption of standards-compliant PETs like BBS+ signatures and accumulator-based revocation to enforce privacy-by-design principles in digital identity systems.
2. **For Organizations:** Invest in scalable verifier infrastructure and establish clear governance frameworks for key management and credential lifecycle policies to ensure trust and regulatory compliance.
3. **For Future Research:** Explore the integration of post-quantum cryptography to ensure long-term security and investigate layer-2 scaling solutions to further reduce on-chain costs and latency.

This study contributes an empirically validated architecture that advances the field of digital identity by demonstrating that privacy, security, and scalability can be effectively balanced. It provides a technical foundation for building a more trusted, user-centric, and secure digital workforce for the future.

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EFFECT OF MARKETING STRATEGIES ON PERFORMANCE OF FISH FARMERS IN MINNA NIGER STATE

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Abstract

The study examined the effect of marketing strategies on the performance of fish farmers in Nigeria, with a particular focus on the four key marketing mix components: pricing, promotion, product, and place/distribution strategies. Fish farming sector plays a vital role in food security, employment generation, and economic development in Nigeria, yet performance levels among small-scale fish farmers remain low. The study synthesised literature on the conceptual and practical dimensions of marketing strategies and business performance, highlighting how each strategy influences profitability, market share, and operational efficiency. The concept of fish farming, performance, marketing and market strategy were discussed. The components of marketing strategy which entails pricing strategy, promotional strategy, product strategy and distribution/place strategy were highlighted. The effect of marketing strategies on performance of fish farmers was also emphasised. The study underscored the direct impact of pricing strategy on farm-level revenues and profitability, while market inefficiencies, high input costs, and poor value chain integration limit farmers' ability to set competitive prices. How effective promotional strategies improve market visibility, sales performance, and brand positioning, was explained. Distribution strategies, especially the use of wholesalers and retailers, reduce costs and expand market access were discussed. The review underscored the need for integrated marketing strategies tailored to small-scale aquaculture, as these have the potential to significantly improve financial and operational performance. The study recommends among others that fish farmers should combine pricing, promotion, product diversification, and efficient distribution into a unified marketing plan rather than applying each in isolation.

Keywords: Fish farmer, Marketing strategies, Nigeria, Performance

Introduction

The implementation of an effective marketing strategy can enable businesses to expand their market reach, enhance brand recognition, establish a competitive edge, and attain substantial sales growth. Small business enterprises possess the dimensions of marketing strategies which includes; price, product, place/distribution and promotion (Ebuzoeme, 2024; Kwarar et al., 2024). These dimensions of marketing strategy operate in tandem and adequate business performance requires a measure of performance in each dimension. The employment of marketing strategies is not only a preserve of large companies but small businesses too can adopt various marketing strategies (Abiodun and Kolade, 2020). Performance is a post business operation activity used to determine how economically well or profitable the business has done within a particular period; it is the extent to which goals or obligation of a firm is being accomplished (Augustine et al., 2020). This study shall conceptualise performance both in financial (profitability) and operational performance (market share, size and sales growth) as suggested by Wiklund and Shepherd (2005). These key strategies must be coordinated and moved into a unified effective marketing strategy if the business must perform well (Chaurani, 2024).

Concept of Fish Farming

Fish farming accounts for small share of global economy as it remains central to the lives of many people in developing countries where most of the world's farmers are found (Pawlak and Kolodziejczak, 2020). The fish industry which is part of livestock agriculture holds a significant impact on a global economy, acting as a cornerstone for both sustenance and economic stability (Food and Agriculture Organisation [FAO], 2020). Fisheries and agriculture provide food and work all over the world, especially in developing countries (Elayna *et al.*, 2018). According to the World Bank as cited in Saba *et al.* (2024), fisheries contribute approximately 270 billion dollars to global Gross Domestic Product (GDP) annually. In Nigeria, over 1.477.651 people are reportedly engaged in the fisheries business (Food and Agriculture Organisation (2020). The sector contributed 1.09% to Nigeria's Gross Domestic Product (GDP) in 2022 (National Bureau of Statistics [NBS], 2017). The sector is predominately occupied by small scale fish farmers (Odioko and Becer, 2022). The sector not only provides employment, but also contributes to food security across the country (Cheke, 2014).

Despite the enormous contributions of this sector to the economy, the fish farmers continue to perform poorly (Mudashiru, 2025). Previous research studies in Nigeria reported low performance of small-scale fish farmers in Nigeria (Ebukiba and Anthony, 2019; Gomna *et al.*, 2020). Performance of any business enterprises is essential for its success and survival (Kawar *et al.*, 2024). Performance have typically been divided into financial and non-financial elements. Financial performance includes a wide range of metrics such as profits, sales, and return on investment while non-financial measures include efficiency of internal processes, market share, and product development (Charles and Bupe, 2024). According to Irfan *et al.* (2021), eight dimensions are commonly used by researchers to measure business performance, namely growth, profit, size, liquidity, success/failure, market share, efficiency and leverage. Also, according to Stam *et al.* (2014) small business performance can be explained through three dimensions, namely growth performance, profitability, and non-financial performance. The measure of growth consists of sales growth, profits, employment, and market share (Stam *et al.*, 2014).

Concept of Performance

The performance of the agriculture sector is an essential aspect of the global economy as the sector has become a significant means of employment, food security, enterprise development, foreign exchange earnings, and means of livelihood for many people globally (Odioko and Becer, 2022). Business owners use business performance to track the completion of company goals and objectives; investors use business performance to measure certain financial and productivity indicators; management uses business performance to analyse past performance and make necessary adjustments in the future; and employees use business performance to track productivity to meet bonus payment criteria (Lee *et. al.*, 2015). Performance integrates aspects such as the efficiency and effectiveness of a company in the use of resources (Egbunike and Okerekeoti, 2018; Mahrani and Soewarno, 2018) and in achieving objectives (Suhadak *et al.*, 2019). According to Richard *et al.* (2009) firm performance has been proposed as a multidimensional construct consisting of many varied areas such as operational effectiveness, corporate reputation and organizational survival. Hamann and Schiemann (2021) indicate that organisational performance has four dimensions: profitability, liquidity, growth, and stock market performance.

Consequently, there are eight dimensions commonly used by researchers to measure business performance, namely Growth, Profit, Size, Liquidity, Success/Failure, Market Share, efficiency and Leverage. The growth performance is explained in the growth of financial and operational performance. The financial performance consists of profit, growth and profitability ratios such as profit margin and returns on investment (ROI). Different criteria for measuring the performance of a company actually relies on measuring the performance itself. Yardstick is unique, because of their specificity on every business, among other fields and sizes of businesses (Taouab and Issor, 2019). The performance of small business enterprises like small fish farmers is the achievement of the small businesses objectives as they are usually established in achieving profit to be able to sustain growth and development. Company's performance can be seen on the profitability, the company's main achievement, and growth (Okerekeoti, 2021). Profitability dimension is intended to determine the company's ability to generate earnings and to find out how far the company is managed effectively (Kurniasih and Akhmadi, 2024).

Concept of Marketing

According to Wenqing (2023), marketing has been practiced for thousands of years, but marketing theory only emerged in the early 20th century. In 1985, the American Marketing Association (AMA) defined marketing as planning and executing business ideas, goods and services, price decisions, promotions, and distribution, through which exchange and learning activities are created to meet individual and organizational goals. In another conceptualisation, Kotler (2003) defined marketing as a set of sales tools commonly used to help companies target customers. The study and practice of marketing have broadened considerably, from an emphasis on marketing as a functional management issue, to a wider focus on the strategic role of marketing in overall corporate strategy (Lestari, 2023). This broadening of the marketing concept, to include strategic as well as operational decisions, has resulted in an overlap between marketing and strategic management.

The emergence of a more open world economy, the globalisation of consumers tastes, and the development of a worldwide commercial web all have increased the interdependency and interconnections of markets across the globe. Furthermore, marketing has evolved from being product centred to customer-centred. This shift reflects the importance of understanding customer behaviour and delivering personalized experiences (Jalal and Elmaghraby 2024). In small scale fish farming, effective marketing strategies can significantly influence customer acquisition, product recognition and overall business performance.

Concept of Marketing Strategy

Marketing strategy can be defined as a method by which a firm attempts to reach its target markets. Marketing strategy entails integrated pattern of decisions that specify its crucial choices concerning products, markets, marketing activities and marketing resources in the creation, communication and/or delivery of products that offer value to customers and enables the organisation to achieve specific objectives (Varadarajan, 2010). Marketing strategy addresses specifically how to act to achieve the desired results. Market conditions are particularly important, because marketing strategy allows the assessment of market dynamics and responds to it (Su *et al.*, 2024). A marketing strategy refers to a meticulously formulated plan or approach developed by organisations with the aim of accomplishing their marketing objectives (Madhavedi *et al.*, 2021). The process encompasses a sequence of actions and choices undertaken to facilitate the

promotion, distribution, and sale of a company's products or services to consumers or its designated market (Wikansari *et al.*, 2022).

Marketing strategy starts with market research, in which needs and attitudes and competitors' products are assessed and continues through into advertising, promotion, distribution and where applicable, customer servicing, sales and distribution (Karam *et al.*, 2018). Marketing strategy must focus on delivering greater value to customers and the firm at a lower cost (Van, 2025). According to Ebitu (2016) marketing strategy entails providing quality product that satisfies customer needs, offering affordable price and engaging in wider distribution and back it up with effective promotion strategy. Marketing strategy is a vital prerequisite of Industry's ability to strengthen its market share and minimize the impact of the competition. In this study, marketing strategy entails.

Components of Marketing Strategy

The components of marketing strategy include pricing strategy, promotional strategy, product strategy and distribution/place strategy.

Pricing Strategy

Pricing strategy is the policy a firm adopts to determine what it will charge for its products and services (Bonnici and Derek, 2015). According to Dhivya and Lavanya (2025), price should reflect the supply and demand relationship. Furthermore, Hussien (2022) posited that pricing is the marketing variable that is the easiest to change while the product or promotion can take months to change, the price can be changed directly. Apart from being the easiest and fastest to change, pricing is also the cheapest to change. While changing promotion, products or distribution is usually quite costly, the opposite is true when it involves the price element (Akinseye *et al.*, 2022). Price is one of the most effective tools in determining the profits of enterprises). Therefore, businesses that do not have a well-planned price policy and strategy are less likely to be successful in the market (Vural and Baltaci, 2022). Pricing strategies are used by companies to help in their evolution on the market and they are set depending on the characteristics of the market where they want to enter at a time (Căruntu and Căruntu, 2011).

The price is an index of the ratio of the commodity to the currency exchange, or the price is the currency performance of the value (Wenqing, 2023). Price represents the conversion of exchange value for goods produced during circulation. In modern market economics, price generates the interaction and balance between supply and demand. It is based on different market positioning, and different price strategies formulated. Price is an essential source of profit generation in the marketing mix. At the same time, the other three are cost generation, which also play different but important roles in various transactions in the market (Charles and Bupe, 2024). Price strategy is a key component of value sent to customers through market offers. Price impacts the cost and perceived quality according to customer value, thus the ability to manage prices effectively is an important marketing strategy (Morgan, 2012).

Promotion Strategy

Promotion is a form of communication used to inform, convince or remind the public about the goods, services, image and community involvement of a person or organization (Alexandrescu and Milandru, 2018). Promotion strategy refers to the various methods and tools such as

advertising, social media, branding, sales promotions, and extension services that are used to inform, persuade, and influence target markets. It is important to remind customers of the benefits of the sold products as compared to those of the competitors and to convince them of this (Alexandrescu and Milandru, 2018). Promotion is the function of information, persuading and influencing the consumers' Purchase decision (Dacula Jr *et al.*, 2025). Promotion can be defined as “a direct inducement that offers an extra value or incentive for the product to the sales force, distributors, or the ultimate consumer with the primary objective of creating an immediate sale” (Mukeshimana, 2016). Promotion is essentially an acceleration tool, designed to speed up the selling process and maximize sales volume. According to Karam *et al.* (2018), promotion is the key to the market exchange process that communicates with present and potential stakeholders, and the general public.

Promotion is considered the set of marketing techniques or practices, marketing action, form of communication. The aim of promotion activities is to capture customers' attention and attract potential buyers, through points of sale, information, belief, training and maintaining a customer interested in the product and the manufacturing company. Promotional strategy is represented by the combination of the methods and techniques used in the promotion and coordination of activities in order to achieve the proposed marketing objectives, in conditions of great efficiency (Alexandrescu and Milandru 2018). Promotion is one of the key dimensions of marketing strategy used by businesses to have a positive impact on their profitability (Abiodun and Kolade, 2020). Promotion entails communication activities whose purpose is to move forward products, idea or service in the marketing channel in order to reach the final consumer (Cross, 2018).

Product Strategy

Product are goods and services that a company offers to the target market (Akinseye *et al.*, 2022). Product differentiation as a marketing strategy is a process of creating superior customer value (Kotler and Armstrong, 2013). The product on offer has to be different from other similar products in the market in order for consumers to purchase it (Nan, 2023). Products can be tangible physical commodities, people and organizations, or intangible forms of services, information, ideas, and locations, the product itself is the main factor affecting the use and experience of consumers and is also the basis of the marketing mix (Wenqing, 2023). A product is all the goods (tangible) and services (intangible) that an enterprise provides to the target market to meet the needs of customers (Kotler and Armstrong, 2013). Thus, a product is more than just a tangible good, and the definition has expanded to include services and benefits and services that can derive from the product.

Product strategy is widely used to refer to that strategy developed by a business to determine the mix of products it wishes to make available in the market-place. It defines the strategy employed in the marketing of a particular product, without necessarily any reference to other products within the product mix of the organization (Kawar *et al.*, 2024). Product strategy is conceptualised as the degree of influence of the product in the marketing mix (Wenqing, 2023). Product as goods or services presented by the business is packed with advantages which the marketer presents to the customers for a price (Madhavedi *et al.*, 2021). Products that exhibit a high level of competition are more likely to acquire a greater portion of the market, cultivate a loyal customer base, and achieve superior sales performance (Sudirjo, 2023).

Distribution/Place Strategy

This refers to the channel of distribution and activity in delivering services or products from providers to receivers (Kotler and Keller, 2016). Distribution/place is the third element of the marketing mix, and it encompasses all decisions and tools which relate to making products and services available to customers (Karam, 2018). According to Pordehghan (2015), distribution refers to activities that are done to deliver a product or service to customers. Distribution or place strategy helps in delivering products to the customers, which also can be said that place helps the consumers reach or find the products to the (Paniandi *et al.*, 2018). Place is not only putting a product in a certain place, but it is about choosing a position that is accessible to potential buyers (Malau, 2020). Place typically means where customers acquire a particular good or enlist the help or support provided by a given service offering (Acutt, 2020). Place is also considered as distribution which is an activity in delivering products to consumers, place and distribution helps consumers reach or find the products (Sudari *et al.*, 2019). Distribution (place) strategy is also called channel because it is as the process and methods by which products or services reach customers (Malau, 2020). Placement or distribution comes with a deep understanding of where your target market is, and how do you distribute your product to them.

Product could be distributed by choosing distribution strategies which are intensive distribution, exclusive distribution, selective distribution and franchising (Isoraite, 2016). Distribution can also be conceptualised as a group of interdependent organisations that help make products or services available to consumers, including a series of institutions that perform all activities to transfer products and their ownership from production to consumption (Kotler *et al.*, 2010; Lim, 2023). According to Wenqing (2023), there are many intermediaries in the place strategy, these include wholesalers, agents, retailers, the Internet, among others. These intermediaries must overcome many barriers between products, services, and consumers, such as time, space and ownership among other.

Effect of Marketing Strategies on Performance of Fish Farmers

Studies have shown that one of the ways of enhancing business performance is through the implementation of an effective marketing strategy (Chaerani, 2024; Dhivya and Lavanya, 2025). Marketing strategy is a long-term planning for achieving a successful performance of business (Lelo *et al.*, 2023). Marketing practice in the 21st century is becoming tough; the marketplace in many countries is so dynamic that to perform well, it is not enough to acquire knowledge of traditional marketing concepts and tools alone (Dambo and Igoni, 2023). Marketing strategy plays a great role in enhancing the overall firm performance which include sales performance, financial performance and market performance (Lelo *et al.*, 2023). There have been studies on the relationship between marketing strategies and business performance (Su *et al.*, 2024; Van, 2025; Dacula Jr *et al.*, 2025). These studies have generally shown that marketing strategies are central to business performance of large business enterprises. Scholars have emphasized the importance of marketing strategies for small enterprises (Boma and Igoni, 2023; Ikudaisi *et al.*, 2024). It is clear that marketing strategy can drive performance (Abiodun and Kolade, 2020). It is very important for business ventures whether large or small to develop appropriate marketing strategies that will enable them to perform well. These strategies are in the areas of product, pricing, promotion, and place.

Pricing strategy is a key determinant of farm-level performance in Nigerian aquaculture because it directly affects revenue, profitability, and the ability of farmers to cover variable and fixed costs. Fish farming in Nigeria reported that high and volatile input costs (particularly feed and fingerlings) constrain farmers' capacity to adopt competitive pricing that still protects margins; where farmers adopt cost-covering or cost-plus pricing approaches they tend to show better profitability and investment capacity. Market structure and price transmission dynamics mediate how much of final consumer prices reach producers.

The integration of price across nodes of the Nigerian fish value chain find incomplete transmission of retail price signals to the farm gate, and evidence of asymmetric transmission in some cases. These market frictions caused by fragmentation of the value chain, many intermediaries, and weak market integration mean that producers often fail to capture full increases in downstream prices or are exposed to aggressive buyer bargaining, which weakens farm performance unless pricing and marketing strategies are improved. Because fish is perishable, discounting and timing decisions are commonly used pricing tools. Fish farmers and marketers frequently use quantity, seasonal and customer-targeted discounts to move stock quickly and reduce spoilage losses. While such discounting improves throughput and may lower per-unit fixed cost, poorly designed discounts can erode margin especially when production costs are high so discount strategies must be targeted and coordinated.

Pricing strategy matters for farm performance through its immediate effect on revenues, interactions with market structure, value-addition opportunities, risk management mechanisms, and information access. Effective promotional strategies can enhance market visibility, drive sales, improve brand positioning, and ultimately boost farm performance. Effective promotion directly improved sales and profitability, proper brand positioning enhances perception and competitive edge, cooperative efforts amplify bargaining power, reduce waste, and strengthen market access. Product choice such as fresh versus smoked fish do influence profitability. For example, smoked fish generates more profit than fresh fish. Limited access to quality feeds and technologies can undermine product strategies. Strengthening distribution channels supports customer retention and business sustainability. The use of wholesalers and retailers as channel of distribution can improve farming system efficiency and reduce distribution costs, especially when markets are distant from farm.

Conclusion

The study concluded that marketing strategies play a central role in shaping the performance outcomes. Pricing decisions directly influence revenue generation, cost recovery, and profitability, but are often constrained by volatile input prices, poor market integration, and intermediary dominance. Promotion remains a critical tool for boosting sales, enhancing brand perception, and improving bargaining power, yet its potential is underutilised by small-scale farmers. Product strategies, offer significant profit advantages and resilience against market price fluctuations. Distribution strategies that leverage wholesalers, retailers, and improved logistics strengthen customer access and reduce waste, thereby enhancing sustainability. Ultimately, the successful integration of these strategies requires not only technical and marketing knowledge but also institutional support, infrastructure development, and improved access to market information.

Recommendations

Based on the review, the following were recommended.

- i. Fish farmers should combine pricing, promotion, product diversification, and efficient distribution into a unified marketing plan rather than applying each in isolation.
- ii. Fish farmers' cooperatives should be created to strengthen bargaining power and reduce price exploitation by intermediaries and emphasise training on packaging, quality control and product differentiation
- iii. Fish farmers should increase market visibility through branding, targeted advertising, and social media engagement.
- iv. Government agencies and development partners should facilitate access to affordable inputs, market information systems, and capacity-building programmes.
- v. Government agencies should support fish farmer cooperatives with credit facilities, marketing hubs, and export opportunities.
- vi. Small and medium enterprises development agency of Nigeria should encourage fish farmer to use mobile applications and online marketplaces for direct marketing, customer engagement, and real-time price updates.
- vii. Government should tailor policies aimed at capacity building initiatives, training and grants that align with real market needs of fish farmers.

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QUANTITATIVE ANALYSIS OF VERTICAL ELECTRICAL SOUNDING DATA ACQUIRED ALONG PROFILE 10 OF THE 8 KM² PHASE II DEVELOPMENT, GIDAN KWANO CAMPUS, MINNA, NIGERIA

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Abstract

In line with the wider programme of continuously seeking refinements to the hydro-centric deductions arising from different modes of studies initiated at the southern Phase II Development, Gidan Kwano Campus, Minna, Nigeria, it becomes most fitting to process a suite of acquired vertical electrical sounding data that was omitted in the earlier processing schedule for this Development. This wilful omission was due to the fact that the principal corpus of the VES data available for the processing schedule was acquired in the transverse traverse format whilst the suite of the VES data of interest herein was acquired in the longitudinal traverse format. The log-log plots indicate that, along the six stations of the P10 traverse, there are two stations designated as two-layer locations, two stations designated as three-layer locations, and two stations designated as four-layer locations in that coincident even format, although the three-layer structure is the expected norm at the local basement geological province. Whereas, too, the norm is to have a comparatively high resistivity value for the third layer of a discerned three-layer geological structure at a general area of survey at the local basement complex geological province in ordinal format, this is not the case for the three-layer P10-11 and P10-12 locations, as well as for the four-layer P10-13 and P10-15 locations. The two-layer locations of P10-14 and P10-16, being “out-of-the-norm” represent “expected geological log-log plot anomaly.” For this study, three tiers or series of interpretation schedule was employed to determine the VES survey station that could most appropriately be tagged “hydro-centric” or water-bearing: the “protocol of Ackworth (1981),” the set-piece “desired outcome” interpretation schedule, and the protocols of the Geoexplore Empirical Standardisation for Minna Area. As a result of these dependable rules-of-thumb, Stations P10-11, P10-12, P10-13, and P10-15 are flagged as groundwater prospect locations and therefore fit to be tagged as “hydro-centric.

Keywords: Vertical-electrical-sounding; longitudinal-traverse; transverse-traverse; resistivity; groundwater; hydro-centric

Introduction

During the 2011 survey year, when inaugural geoelectrical survey of the 8 km² Gidan Kwano Campus Phase II Development (Figure 1) was initiated as part of the cascading long-term programme and series of investigations to create a dedicated reference archive for this new development that is contiguous with the already-congested Phase I Development (Figure 2), vertical electrical sounding (VES) measurements at principal stations along traverse lines were carried out in the north-south or south-north longitudinal traverse (LT) sense. The grid of the 8 km² area, at 100-m spacing-distance for each red dot that corresponds to the principal station of the planned geoelectrical survey scheme, is shown as Figure 3. The segmented grid-layout of Figure 3 is designated in a left-to-right format as having Profile 1 as the westernmost north-south or south-north traverse line, as the case may be. Thus, there are 21 south-north traverses for the grid of Figure 3. At the onset of survey, measurements proceeded in a south-north fashion along

P11, the central LT, for the designated 41 principal stations along this 4 km linear extent although the data-collection scheme was not without hitches at the time of survey because of barriers that impeded measurements at some stations along this traverse, specifically tilled farmlands that would not be disturbed by the investigating crew. A survey scheme of this nature, being constraint by cost and lack of other associated resources on the part of the principal investigator would not, naturally, follow a smooth pattern of survey succession beginning at the south-end of a new LT upon completing data collection at a preceding LT. Thus, it was that even before data collection exercise was completed for P11, convenience and cost-saving measures meant that measurements were initiated at some principal stations along P10, not necessary beginning from the first principal station of P10 or P10-1; thus, measurements were completed at P10-11, P10-12, P10-13, P10-14, P10-15, and P10-16 in the LT sense. Jonah (2024^a) referenced these measurements in his study concerning employing longitudinal traverse vertical electrical sounding resistivity data-sets as veritable controls for hydro-centric deductions at the southern Phase II Development, Gidan Kwano Campus, Federal University of Technology, Minna. The author pointed out that the validation scheme therein was a veritable qualitative-verification process since the suite of VES data acquired at P10-11, P10-12, P10-13, P10-14, P10-15, P10-16 in longitudinal traverse mode has not yet been processed quantitatively. The thrust of this thesis is, therefore, most fitting, the quantitative analysis of the result of processing this suite of data. This effort would be in line with the wider programme of continuously seeking refinements to the hydro-centric deductions arising from different modes of studies initiated at the southern Phase II Development.

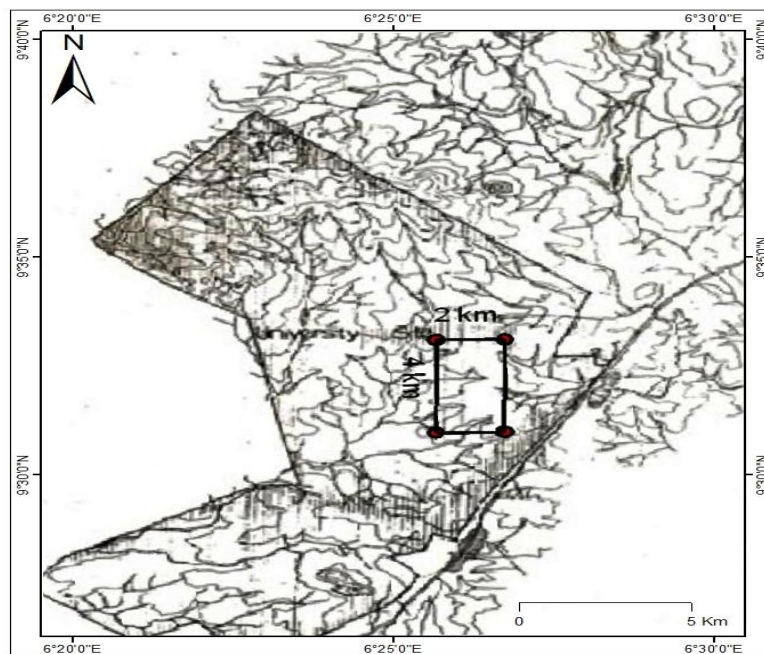


Figure 1. The 8 km² Phase II Development shown inscribed on a georeferenced map of the Gidan Kwano Campus

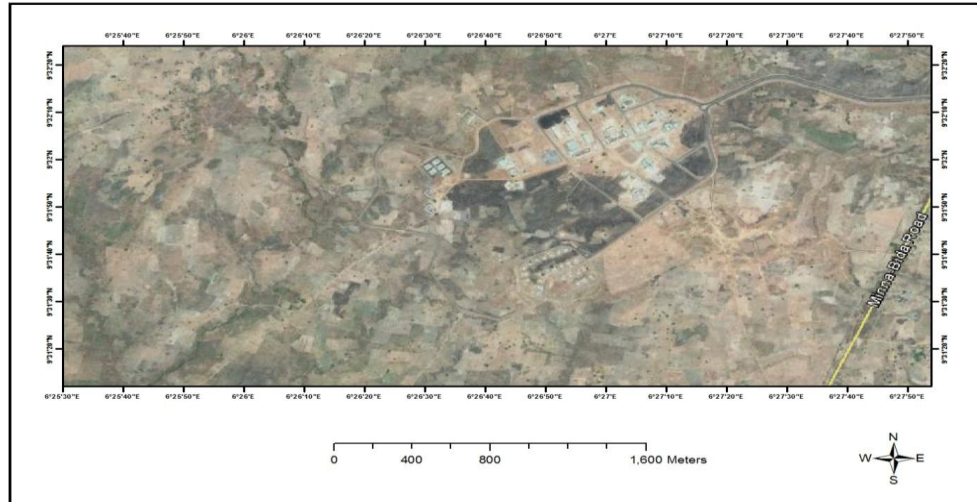


Figure 2. Satellite-image map of a portion of the Gidan Kwano Campus showing the ringed-off Phase I Development. (The tadpole-shaped feature is the Phase I Development; the Minna-Bida Road is seen as the linear slope to the east.)

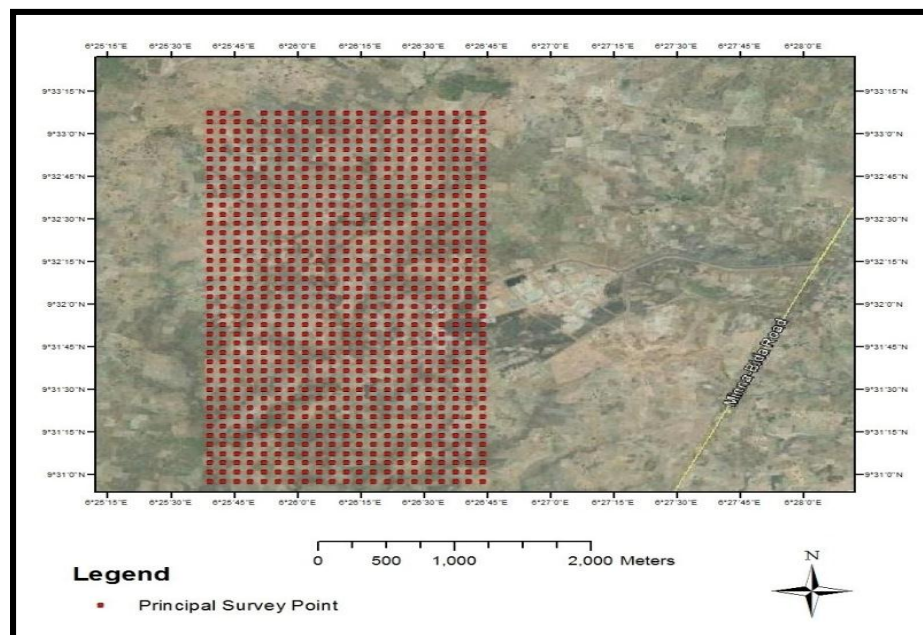


Figure 3. Grid of the 8 km² Phase II Development against the backdrop of a satellite-image map showing the Phase I Development. (The Minna-Bida Road is seen as the linear slope to the east.)

The aim of this study is implementing quantitative analysis of vertical electrical sounding data acquired along the tenth profile of the 8 km² Phase II Development, Gidan Kwano Campus, Minna, by the route of the following objective format: generation of log-log plots and their analyses thereof. The result of this study would help refine the deductive outcomes of the Jonah and Olasehinde (2017) study regarding exploitable groundwater prospects at the southern Phase II Development, especially.

Study Area

The 8 km² Phase II Development. The 8 km² Phase II Development of the Gidan Kwano Campus is approximately 1/12th of the total areal extent of the Gidan Kwano Campus; the defined 8 km² areal extent is located at the east-central portion of the Gidan Kwano Campus between latitude 9°30'57.8":9°33'07.4" and longitude 6°25'39.0":6°26'43.8". The 8 km² Phase II Development is shown inscribed on a georeferenced map of the Gidan Kwano Campus as Figure 1; this 8 km² area, actually contiguous with the developed portion of the Gidan Kwano Campus where expansions to the existing students' hostel facilities and other structures are planned, was defined in accordance with the groundbreaking launch in 2011 indicated by the stone plaque at the point of latitude 9°31'53.7" and longitude 6°26'23.5". The developed portion of the Gidan Kwano Campus (the less than 2 km² Phase I Development) is as seen in Figure 2.

The Gidan Kwano Campus. The Gidan Kwano Campus, slightly greater than 100 km² and located along the Minna-Kateregi-Bida Road, lies between latitude 9°26'15" and 9°37'30": longitude 6°23'15" and 6°28'45" (Adesoye, 1986). Of particular interest about the Gidan Kwano Campus is its horse-shoe shape.

Conversion of Resistance Values to Apparent Resistivity Values. The resistance values at each survey point out for the six principal stations of Profile 10 need to be converted to the true resistivity values of the inhomogeneous earth known as the apparent resistivity values. This would be determined by multiplying the acquired resistance value for each row by its corresponding geometric factor.

Analytical Derivative of Log-Log Plots. Usually, after determining the resistivity values from the field resistance values, it is desirable to generate curves, commonly known as "log-log plots," showing the variation of resistivity values with the total depth surveyed at that particular sequence for each VES station. It is recognised that the effective depth of penetration is equal to half the current electrodes spacing (if the current electrodes are separated by distance AB, then this AB/2). According to Zohdy (1989), a continuous variation of resistivity with depth curve is easily derived from multilayer step-function curve by drawing a curve that passes through the logarithmic midpoint of each vertical and horizontal line on the multilayer step function model. In view of the fact that the layer depths are logarithmically closely-shaped, the derived continuous variation of resistivity with depth model is equivalent to the original model. This approach makes it easy to construct maps of contoured resistivity values at different depths and to construct contoured geoelectric sections. The field resistivity values would be subjected to the log-log plot routine of the Windows-compatible WinResist[®] software whence corresponding field curves for all the stations occupied would be produced.

Review of Literature

Geology of Nigeria

According to Obaje (2009), the geology of Nigeria is made up of three major litho-petrological components, namely, the *Basement Complex*, *Younger Granites*, and *Sedimentary Basins*. The Basement Complex, which is Precambrian in age, is made up of the *Migmatite-Gneiss Complex*, the *Schist Belts* and the *Older Granites*. The Younger Granites comprise several Jurassic magmatic ring complexes centered on Jos and other parts of northcentral Nigeria. They are structurally and petrologically distinct from the Older Granites. The Sedimentary Basins, containing sediment fill of Cretaceous to Tertiary ages, comprise the Niger Delta, the Anambra Basin, the Lower, Middle and Upper Benue Trough, the Chad Basin, the Sokoto Basin, the Mid-Niger (Bida-Nupe) Basin and the Dahomey Basin. Abundant mineral deposits occur in all the components of Nigerian geology (Basement, Younger Granites, and Sedimentary Basins). Solid mineral deposits of economic significance that include gold, iron ore, cassiterite, columbite, wolframite, pyrochlore, monazite, marble, coal, limestone, clays, barites, lead-zinc, et cetera, occur in the different geologic segments of Nigeria and indeed each of the 36 federating states and the Federal Capital Territory has a fair share of the solid mineral inventory of the nation. Oil and gas, on the other hand, proliferate in the Niger Delta Basin with opportunities to add to the national reserve asset existing in the other sedimentary basins, namely the Anambra Basin, the Benue Trough, the Chad Basin, the Sokoto Basin, the Bida Basin and the Dahomey Basin.

Regional Geology of the Study Area

It is known that, at the area of study, which is part of the Nigerian Basement Complex (NBC), the regional geological signature can be described in terms of a migmatite-gneiss complex, the schist belts, and an older granite suite. According to Adesoye (1986), the Gidan Kwano Campus constitutes a tiny southern tip of the NBC occurring in northcentral Nigeria. According to Obaje (2009), the basement complex is one of the three major litho-petrological components that make up the geology of Nigeria. The NBC forms a part of the Pan-African mobile belt and lies between the West African and Congo Cratons and south of the Tuareg Shield (Black, 1980). It is intruded by the Mesozoic calc-alkaline ring complexes (Younger Granites) of the Jos Plateau and is unconformably overlain by Cretaceous and younger sediments. The Nigerian basement was affected by the 600 Ma Pan-African orogeny and it occupies the reactivated region which resulted from plate collision between the passive continental margin of the West African craton and the active Pharusian continental margin (Burke and Dewey, 1972; Dada, 2006). The basement rocks are believed to be the results of at least four major orogenic cycles of deformation, metamorphism and remobilization corresponding to the Liberian (2,700 Ma), the Eburnean (2,000 Ma), the Kibaran (1,100 Ma), and the Pan-African cycles (600 Ma). The first three cycles were characterized by intense deformation and isoclinal folding accompanied by regional metamorphism, which was further followed by extensive migmatization. The Pan-African deformation was accompanied by a regional metamorphism, migmatization and extensive granitization and gneissification which produced syntectonic granites and homogeneous gneisses (Abaa, 1983). Late tectonic emplacement of granites and granodiorites and associated contact metamorphism accompanied the end stages of this last deformation. The end of the orogeny was marked by faulting and fracturing (Gandu *et al.*, 1986; Olayinka, 1992). Within the basement complex of Nigeria four major petro-lithological units are distinguishable, namely:

- i. The Migmatite–Gneiss Complex (MGC)
- ii. The Schist Belt (Metasedimentary and Metavolcanic rocks)
- iii. The Older Granites (Pan African granitoids)
- iv. Undeformed Acid and Basic Dykes

Geology of the Gidan Kwano Campus

According to the site survey report completed by the firm of Adesoye and Partners (Adesoye, 1986), the Gidan Kwano Campus constitutes a tiny southern tip of the Nigerian Basement Complex (NBC) occurring in northcentral Nigeria. The major rock types mapped in the area consist of schists (that is, quartz mica schist and quartz-bearing phyllitic schist), granite gneiss, biotite-hornblende granite, muscovite-biotite granite, pegmatite, and vein quartz. About 50-60 % of the entire land area of the central parts is underlain by granitic bodies of hornblende-biotite granite and biotite-muscovite granite. These are ringed to the south by the granite gneisses which also occur to the north. A subordinate amount of mica schists is located at the northeast and this may be a southward extension of a layer of body of schist. The major rock types are described in the following subsections with respect to their megascopic and microscopic characteristics.

The Schists. These comprise of the quartz-mica schist and the quartz-phillite schist. The mica schists are mainly quartz-biotite-muscovite schists which grade into coarse-grained plagioclase-bearing mica schists. They occur as small low-lying bodies exposed mainly along road cuttings, eroded paths, and to medium-grained schist rocks which tend to split along schistosity planes. Some of the schists are sheared. The quartz-bearing phyllitic schists occur two kilometers southwest of Gidan Kwano. It is composed of quartzitic and phyllitic members closely bound together. The gradational interface comprises of loose coarse grains of muscovite. The phyllite member is fine-grained and easily split along the schistosity or parting plane. Mineralogically, the rock is made up predominantly of biotite-muscovite which constitutes about 61%, and quartz which constitute about 35%. The biotite and the muscovite occur as blade-like columnar crystals. They are also perfectly aligned along the foliation direction. These characteristics have facilitated the splitting of the rock into pieces, thereby facilitating quick weathering of the rocks.

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Granite Gneiss. The granite gneiss is the second-largest occurring rock type in the Gidan Kwano Campus. The occurrence is concentrated into two areas in the northern and extreme southern parts. Those of the northeastern parts are rather small and possibly represent the southern extremity of a larger body to the north. The outcrops are usually elliptical in shape and rise a few metres above the ground surface. The rock weathers parallel to the strike. Occurrences of this rock were noticed in the southern parts from about two kilometers south of Dan Zaria along the road through Garatu and further south to the end of the Gidan Kwano Campus. Here, the rock crops out as low-lying bodies, except at Garatu Hill where an elevation of 240 m above the general level was attained. Megascopically, the granite gneiss exhibits faint, poorly developed gneissose structure, the sense of alignment is given by preferred orientation of biotite and hornblende and some feldspar porphyroblasts. Gneissose texture is also affected by fine quartzo-feldspathic veins which tend to mask the few existing joint planes. In essence, the granite gneiss is fine-grained to medium-grained in texture. Locally, porphyroblasts of feldspar are developed in a matrix of mica and hornblende feldspar quartz which are the main constituents of the rock. Under the microscope, the minerals quartz (50%), biotite (20%), hornblende (18%), potassium feldspar (30%) exhibits a granular texture. Phryoblasts of feldspar, set in the mica hornblende feldspar matrix are already being

altered into sericites or partially albitised. Gneissic texture is most prominently shown under microscopic examination. They are well-marked by mica and the hornblende grains which also apportion the mineralogy into unequal differentiated bands.

The Granites. The granite mapped in the Gidan Kwano Campus consists of the hornblende-biotite granite and the muscovite-biotite granite, all of which belong to the Older Granite suite. They are believed to have been emplaced during the Pan-African orogenic event. The granites are the largest group of rocks occurring in the Gidan Kwano Campus. They underlie the northern and the central parts of the Gidan Kwano Campus. They outcrop as relatively large conical hills, especially at Kpaina, Legbe, Dagba, west Gidan Logo, Lunko, and in the vicinity of Gwosa.

Hornblende-Biotite Granite:- The biotite granite occurs to the south of the muscovite-biotite granite and maintains a rather gradational boundary with the granite gneiss in the south. Most of the outcrops are, however, located mainly to the central parts where the topography is rather flat and slightly undulating. The outcrops are somewhat scarce. The microscopic properly of the granite consists of coarse-grained texture which under some slides tend to be porphyritic. The mineralogy consists of quartz (30%), biotite (31%), microcline (22%), hornblende (25%), and varietal accessory that include sphene and opaques. The high proportion of biotite and hornblende imparts a moderate foliation into the rock, and this makes the rock susceptible to weathering.

Muscovite-Biotite Granite:- The muscovite-biotite granites are located mainly to the northern parts of the Gidan Kwano Campus where they are in contact with the granite gneiss and the mica schist. They often outcrop on the low hills and to a limited extent in the low-lying areas. Boulders of the rock are found along stream channels and river banks. Megascopic examination shows that the rock is foliated. The north-south foliation direction is defined by the mica minerals. The rock is susceptible to weathering and this variety, as well as the outcrops along river channels, often appears flabby or deceptively schistose. Such outcrops were found around the Epigi villages (i.e. Epigi I and Epigi II). This granite type is composed of quartz (33%), microcline feldspar (20%), muscovite (28%), and biotite. The rock is rather fine-grained in texture than the hornblende-biotite type. Muscovite crystals occur as laths and are associated with the biotite, both of which define the micro-foliation.

Review of Case Studies

Jonah and Olasehinde (2015) examined the qualitative induced polarisation (IP) validation of the results of a 2 km² VES study completed at the Gidan Kwano Campus Phase II Development. The authors reported that the 2 km² VES study under consideration here was Jonah *et al.* (2015^a) for which no tandem and coincident-point IP data-set was collected in the course of that survey completed in 2013; this 2 km² VES survey was conducted at 200 m principal station-spacing and the areal extent was subsumed within the southern half of the 8 km² total area Gidan Kwano Campus Phase II Development. It is understood that the aim of the study was to provide “a refinement of sorts” or “a further constraint” on the result of the interpretation of the VES survey at the 2 km² slice of Phase II of the Gidan Kwano Campus by employing corresponding IP data set in quality control (QC) mode. All aspects of the tandem VES-IP survey were completed in the transverse traverse trend. For the qualitative discussion herein, examination of each of the separate IP tables of values was fixed for a benchmark depth of 40 m because this 40 m-window restriction was due to the fact that, in the larger basement complex region of which the present area of study is but a small constituent, the thicknesses of the different phases of overburden materials never

exceed 35 m. The authors reported that, based on the analysis of the corresponding IP tables, for which the IP method is the second-stage constraint to the earlier VES interpretation, the aquifer prospects that were tagged “strongly aquiferous” in Jonah *et al.* (2015^a) are now even qualified as “very strongly aquiferous,” meaning that the IP method is a great QC tool like was suggested by Parasnis (1986).

In the desire to explore approaches that are not generally conventional, but ones that have good foundational basis, and part of the series of surveys referred to earlier, Jonah *et al.* (2015^b) conducted a wet-season geoelectrical investigation for groundwater development at a built-up property at the Western Bypass, Minna, Nigeria. The client had already commissioned a dry-season spell survey at the same built-up property, but the result was not known to the present survey crew beforehand. The result of the present endeavour would be essentially corroborative. The vertical electrical sounding mode of the resistivity type of geoelectrical survey employing the Schlumberger array was the preferred format for this exercise. The survey schedule was to do VES to a total depth of 100 m, where possible, although that depth was well beyond the effective water-bearing subsurface environment and into the local bedrock proper. Nonetheless, the built-up nature of the neighbourhood of the survey locations precluded the 100 m-target. In interpreting for possible locations of groundwater, two constraints are used, viz: the “ideal” log-log plot and the “Olasehinde Protocol.” such a log-log plot must have almost all plotted points alternately “rising-and-falling” along the curve and the Olasehinde Protocol states that resistivity values between 180 Ωm and 250 Ωm at the 20 m to 25 m depth-mark is indicative of possible groundwater prospect. Only the third and last survey location approximated these impositions at the 20 m – 30 m depth-mark with a smoothly-varying resistivity profile observed to the 40 m depth-mark, and its corresponding plot indicated a three-layer sequence. Based on the imposed constraints, the survey crew posited that the location of latitude 09°39'36.2" and longitude 006°30'30.2" was the best prospect location identified from this survey. If drilling must be done at all, the survey crew recommended that this location should be drilled to a total-depth of 50 m.

Jonah and Jimoh (2016) examined the validity of an empirical rule for delineating aquifer prospects at the Gidan Kwano Campus. The authors remarked that there existed an empirical rule to determine the likely presence of groundwater in a local Basement Complex geological province but there had not been an independent analytical approach to test this rule yet. The authors analysed results from a 4 km² VES survey according to standard procedures whilst pseudosections along principal profiles were generated and, from a handful of these pseudosections selected for this study, they observed that the basis of this rule is true when aquifer delineation is aided by computer-assisted processing. Thus, they recommended that where the means to analyse VES data for small-scale surveys by computer software are not readily available, recourse to the “Geoexplore Empirical Standardisation for Minna Area” should be adopted when working in a Basement Complex province.

In their study concerned with the interpretation of vertical electrical sounding data of Gidan Kwano Campus Phase II, Jonah and Olasehinde (2017) pointed out that the area of study defined for that survey was ideal for the University’s near-term and mid-term facility expansion programmes as it obviously formed a contiguous landscape with the developed portion of the major campus. The aim of that study was to provide groundwater-location information for the planned tranche of new development at the major campus using much closely-spaced VES data at 100 m-spacing. The Schlumberger array of the vertical electrical sounding mode was employed for the survey. The

survey trend was an east-west (or TT) sense for individual stations and a south-north profile. The scheduled data grid of 21 x 21 stations was processed to obtain information on the log-log plots, the geoelectric cross-sections, the iso-resistivity signatures at different depths of survey, and the pseudosections. It is further understood that the resulting interpretation was a function of all these processing information. The authors reported that tandem induced polarisation information obtained in the course of the survey was employed in a qualitative sense as a tool of quality control in order to constrain the conclusion drawn with respect to the presence of groundwater even further. According to the authors, interpretation of the results indicated a sense of “geological fault-sources” at the right of the central mid-plane much close to the southeast and also a sense of “geological fault-sinks” at some points on the first TT line much close to the southwest. The authors concluded that these “geological fault-sinks” located on the slope of the landform of the area of study were the most important aquifer locations because they are situated on the low-slope of subsurface fault lines.

Ibeneme *et al.* (2014) remark that the different aquifer units within the Lower Orashi River Sub-Basin, Southeastern Nigeria, were delineated using the Vertical Electrical Sounding (VES) technique. The authors observe that twenty-two (22) VES soundings were carried out using the ABEM SAS 4000 Terrameter. The data generated were analyzed using the Zohdy software which outputted modeled curves in terms of depth and resistivity. According to the authors, six profiles were taken in the northeast–southwest and northwest–southeast directions to cover the entire area of study. Four to six geo-electric layers comprising the top soil, clayey sand, dry sandstone, saturated sandstone, shaley sand and sandy shale were delineated with the later usually occurring as the last layer. The third and fourth layers underlying dry sandstone form the aquiferous unit. This unit was found to have an average resistivity value range of 10.7 – 6060 Ωm and an average thickness of 32 m. It was observed that most of the aquifer units within the area are unconfined with static water level varying between 10.6 to 62.8 m. Some of the aquifer units are shallow with static water level less than 40 m while others are deeper with static water level occurring at over 60 m below the surface. It was advised that care ought to be taken in drilling and casing at shallow aquiferous areas to maintain proper sanitary condition so as to reduce the risk of groundwater contamination.

Pacheco *et al.* (2023) explained that, in recent years, the occurrence of unexpected meteorological events during the dry season and population growth generated shortages in the supply of drinking water in the city of Pampas, Peru. This situation prompted the authors to look for new search strategies for natural water sources, including underground sources. The authors observed that faced with this problem, the possibility of detecting and parameterizing these sources was raised, while the design of a tubular well that allows the economic extraction of water from the aquifer was also raised studied; both of these objectives were achieved through the use of geophysical techniques, generating profile images of geological maps of the strata and the location of the possible water table of the study area. The authors pointed out that the preferred locations for locating groundwater collections are alluvial fans and fractured valley bottoms. Using the Schlumberger array, eleven (11) vertical electrical soundings were completed up to a depth of 150 m. The acquired resistivity values vary between 6.32 Ωm and 125.23 Ωm . The PQWTS-150-Water Detector equipment was also used to measure the depth of the semi-confined aquifer and to know its groundwater flow. The authors further noted that the profile of the geological map was described, and in this profile, clayey, silty, sandy, gravelly soils and a combination of them were found. Of particular interest, according to the authors, was VES Point 11 which was surveyed at

the location of the nursery of Daniel Hernández district, the area being flat and humid. The authors noted that the aquifer at VES Point 11 has good hydrogeological possibilities that made surface recharge possible. The water table was also determined to be between 4 m and 8 m. Subsequently, the tubular well was designed. The authors concluded that the well was designed for a total depth of 115 m.

Presentation of Data and Discussion

The computed values of the apparent resistivity values for each row are presented in their correct order after duly multiplying the acquired resistance value for each row by its corresponding geometric factor.

Generation of Log-Log Plots

The field resistivity values were initially subjected to the log-log plot routine of the Windows-compatible WinResist[®] software whence corresponding field curves for all the stations occupied were produced. The initial outputs were the “default” graphs. These were further smoothed by iterations which were done in layers, thus resulting in final “modelled” outputs. The smoothed graphs are those that have connections to all the plotted points on the graph, and these are presented as Figures 4 to Figure 9. Each of the WinResist[®] log-log plot provides information on the numbers of layers, the average resistivity values of these layers, their depths of occurrence, and their approximate thicknesses.

Resistivity Values of Rock Types in the Basement Complex of Nigeria

The resistivity values of various rock types in the Nigerian Basement Complex are presented in Table 1. (From Shuaibu *et al.*, 2004).

Table 1. Resistivity values of rock types in the Basement Complex of Nigeria

Rock Type	Resistivity (Ωm)
Fadama loam	30 – 90
Sandy clay and sandy silt	100 – 200
Sand and gravel laterite	150 – 1000
Weathered laterite	150 – 900
Fresh laterite	900 – 3500
Weathered basement	20 – 200
Fractured basement	500 – 1000
Fresh basement	> 1000

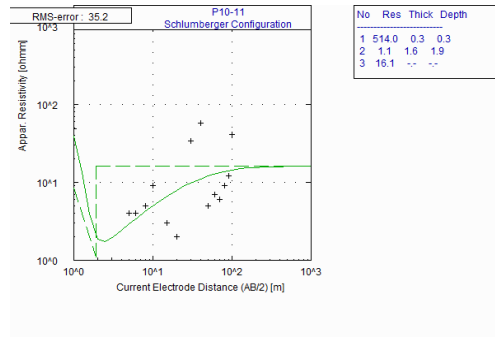


Figure 4. Log-log plot of P10-11

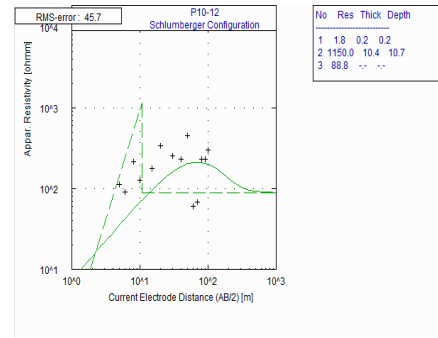


Figure 5. Log-log plot of P10-12

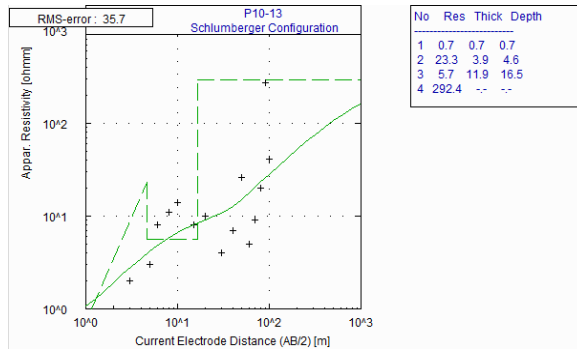


Figure 6. Log-log plot of P10-13

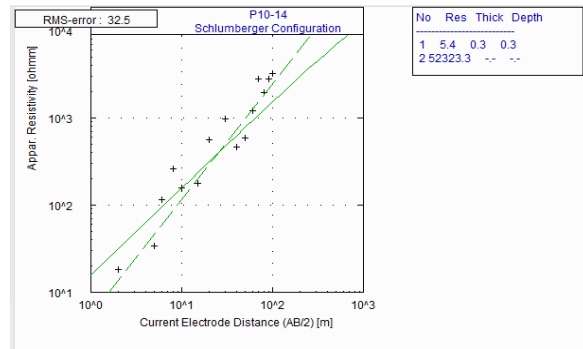


Figure 7. Log-log plot of P10-14

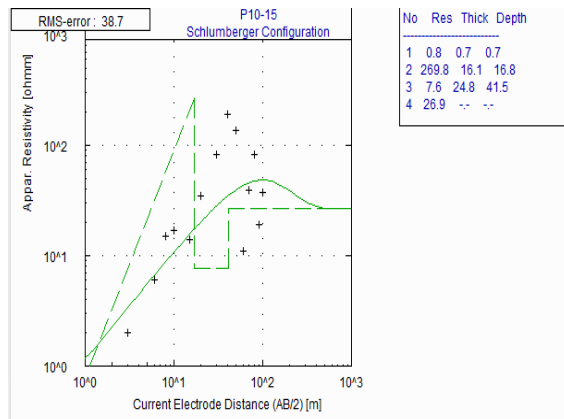


Figure 8. Log-log plot of P10-15

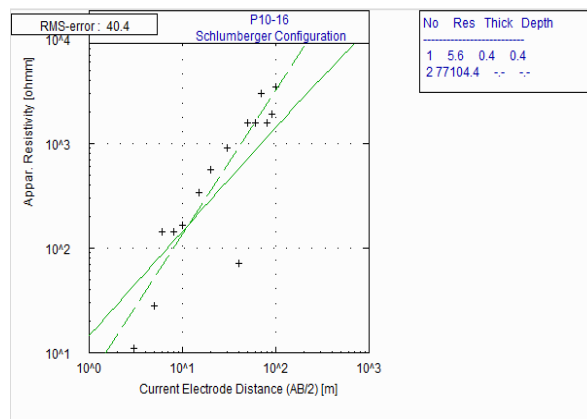


Figure 9. Log-log plot of P10-16

Discussion

“Tricks” for Groundwater Search at the Nigerian Basement Complex. There exists, for the Nigerian Basement Complex, empirical rules (as complements to the “traditional” interpretation sequences that are taught in schools) by which workers can reliably make deductions with respect to presence of sustainable groundwater at VES survey points along a line or across an area of study. Loke (2001) quoted Acworth (1981) as stating that, “the weathered layer is thicker in areas with fractures in the bedrock.” Jonah and Jimoh (2016) examined the validity of an empirical rule for delineating aquifer prospects at the Gidan Kwano Campus Development Phase II, Federal University of Technology, Minna, and this reliable route has been christened “Geoexplore Empirical Standardisation for Minna Area;” the Geoexplore Empirical Standardisation for Minna Area states that resistivity values between 200 Ωm and 300 Ωm at the 20 m depth and less than 200 Ωm at depths greater than 20 m are indicative of possible groundwater prospects. These recognised empirical rules, the veritable “tricks” for groundwater search at the Nigerian Basement Complex, are at the complementary core of the rules-of-thumb employed to determine location of a groundwater in the first and the fourth stage interpretation instances schedule according to Jonah (2024).

The Log-Log Plots. The log-log plots indicate that, along the six stations of the P10 traverse, there are two stations designated as two-layer locations, two stations designated as three-layer locations, and two stations designated as four-layer locations in that coincident even format, although the three-layer structure is the expected norm at the local basement geological province (Olasehinde, personal communication). Whereas, too, the norm is to have a comparatively high resistivity value for the third layer of a discerned three-layer geological structure at a general area of survey at the local basement complex geological province in ordinal format, this is not the case for the three-layer P10-11 and P10-12 locations, as well as for the four-layer P10-13 and P10-15 locations. The two-layer locations of P10-14 and P10-16, being “out-of-the-norm” as per the Olasehinde personal communication statement, represent what could be referred to herein as “expected geological log-log plot anomaly” for the mid-section layers of the inferred four-layer locations of Figure 6 and Figure 8 corresponding to the P10-13 and P10-15 stations could be “compressed” into a single layer in order to achieve fidelity to the three-layer specification at the local geological province, especially noting that these mid-section layers show the characteristic of being “thick weathered layers” as gleaned from the protocol of Acworth (1981). Stations P10-11 and P10-12 show a sequence of comparatively low-resistivity values down to greater depths. The greater than 1000 Ωm value of the second layer at P10-12, characterised by its comparative thickness of 10.4 m (Figure 2), with this second layer material corresponding to “fresh basement” as per Table 1 and the third-layer value showing a sudden drop in resistivity value corresponding to plausible fracturing in the fresh basement rock, is the desired outcome for groundwater search at the local basement complex geological province. Thus, for Station P10-12 the “protocol of Acworth (1981)” has been satisfied as well as the “desired outcome” interpretation schedule. For Station P10-11, there exists two very-low resistivity layer sequences beneath the very thin first layer that would appropriately correspond to “fractured basement” as per Table 1 thus placing a little ambiguity on the nature of the fulfilment of the “desired outcome” interpretation schedule. Also, Station P10-11 did not satisfy the “protocol of Acworth (1981)” for there is no indication of a “thick weathered layer” as per Figure 4 even though sequences of low-resistivity layers occur beneath the “fractured basement” material. As per satisfying the conditions of the Geoexplore Empirical Standardisation for Minna Area, the table of station P10-11 being characterised by series of extremely low

resistivity values beyond the 20 m depth-point, does appear, on the face of it, to occur in fidelity to the stated protocols whereas that of Station P10-12 by and by faithfully fulfils the stated protocols. Actually, the location P10-12 is the subject of interest as one of the cross-profile VES stations characterised by plausible faulting regime over a 2000 m extent in the work of Jonah (2024^b).

For Station P10-13, as gleaned from Figure 6, it is inferred that the weathered layer (assumed agglomeration of the second and third geological layer sequences) is comparatively thick for a commulative dimension of 15.8 m but the “desired outcome” interpretation schedule, whence sudden drop of resistivity value of the third layer is observed just immediately following the relatively high fresh basement resistivity specification of the second layer, is not satisfied here. As per satisfying the conditions of the Geoexplore Empirical Standardisation for Minna Area, it is seen that the table of Station P10-13 being characterised by series of extremely low resistivity values beyond the 20 m depth-point, does appear, on the face of it, to occur in fidelity to the stated protocols.

For Station P10-14, the two-layer formation schedule clearly does not conform to the norm of a three-layer formation at the local basement geological province and examination of Figure 7 also indicate that the “desired outcome” interpretation schedule, whence sudden drop of resistivity value of the third layer is observed just immediately following the relatively high fresh basement resistivity specification of the second layer, is not satisfied here. There is also no indication of a “thick weathered layer” in the formation schedule. As per satisfying the conditions of the Geoexplore Empirical Standardisation for Minna Area, it is seen from the table of Station P10-14 that, overwhelmingly, there is no fidelity to the stated protocols.

For Station P10-15, as gleaned from Figure 8, it is inferred that the weathered layer (assumed agglomeration of the second and third geological layer sequences) is comparatively thick for a commulative dimension of 40.9 m but the “desired outcome” interpretation schedule, whence sudden drop of resistivity value of the third layer is observed just immediately following the relatively high fresh basement resistivity specification of the second layer, is not satisfied here. As per satisfying the conditions of the Geoexplore Empirical Standardisation for Minna Area, it is seen that the table of Station P10-15 does appear, on the face of it, to occur in fidelity to the stated protocols.

For Station P10-16, the two-layer formation schedule clearly does not conform to the norm of a three-layer formation at the local basement geological province and examination of Figure 9 also indicate that the “desired outcome” interpretation schedule, whence sudden drop of resistivity value of the third layer is observed just immediately following the relatively high fresh basement resistivity specification of the second layer, is not satisfied here. There is also no indication of a “thick weathered layer” in the formation schedule. As per satisfying the conditions of the Geoexplore Empirical Standardisation for Minna Area, it is seen from the table of Station P10-16 that, overwhelmingly, there is no fidelity to the stated protocols.

Interestingly, Station P10-15, characterised by an appreciable regime of weathered layer formation, is “sandwiched” between P10-14 and P10-16, two “rocky locations.” Examination of Table 1 indicates that a significant material of the “weathered layer” for Station P10-15 has “sand” and “gravel laterite” character.

Conclusion

Station P10-11, whilst not outrightly satisfying the “protocol of Acworth (1981),” is in fidelity to the set-piece “desired outcome” interpretation schedule and to the protocols of the Geoexplore Empirical Standardisation for Minna Area, by and large, and thus it is flagged as a groundwater prospect location. Station P10-12 satisfies the “tripartite rule of interpretation” that have been adopted for this study, namely, fidelity to the set-piece “desired outcome” interpretation schedule, the “protocol of Acworth (1981),” the protocols of the Geoexplore Empirical Standardisation for Minna Area, and thus it is flagged as a groundwater prospect location in “assured” mode. Station P10-13 satisfies the “protocol of Acworth (1981)” and the protocols of the Geoexplore Empirical Standardisation for Minna Area but it is not in fidelity to the set-piece “desired outcome” interpretation schedule. Nonetheless, P10-13 is flagged as a groundwater prospect location. Station P10-14 satisfies neither the “protocol of Acworth (1981)” nor the protocols of the Geoexplore Empirical Standardisation for Minna Area and it is not in fidelity to the set-piece “desired outcome” interpretation schedule. Thus, P10-14 is not flagged as a groundwater prospect location. Station P10-15 satisfies the “protocol of Acworth (1981)” and the protocols of the Geoexplore Empirical Standardisation for Minna Area but it is not in fidelity to the set-piece “desired outcome” interpretation schedule. Nonetheless, P10-15 is flagged as a groundwater prospect location. Station P10-16 satisfies neither the “protocol of Acworth (1981)” nor the protocols of the Geoexplore Empirical Standardisation for Minna Area and it is not in fidelity to the set-piece “desired outcome” interpretation schedule. Thus, P10-16 is not flagged as a groundwater prospect location.

The inferred “sand” and “gravel laterite” character discernible at Station P10-15 that is “sandwiched” between two “rocky locations” makes P10-15 a point of interest for any future drilling programme to exploit groundwater based on the outcome of this study.

Stations P10-11, P10-12, P10-13, and P10-15, all being flagged as groundwater prospect locations and therefore fit to be tagged as “hydro-centric” as per Jonah and Olasehinde (2017), can now be incorporated into the list of groundwater locations deduced from the study of Jonah and Olasehinde (2017) and Jonah and Jimoh (2021) regarding exploitable groundwater prospects at the southern Phase II Development.

Since Station P10-11 is flagged as a groundwater prospect location, Station P10-12 is flagged as a groundwater prospect location in “assured” mode, Station P10-13 is flagged as a groundwater prospect location, and P10-15 is flagged as a groundwater prospect location with the character of P10-15 being discerned as “sandy” over a comparatively thick extent, it is recommended that these four locations, still being outside the polluted zone of the burgeoning built-up area that is the students’ hostel facilities, be exploited for their groundwater potentials. If faced with cost-saving drilling measures, then the points of P10-12 and P10-15 should be exploited in the initial phase.

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