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; Asiyanbola, 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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