

## THE ROLE OF ARTIFICIAL INTELLIGENCE ON TRANSFORMING SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS (STEM) EDUCATION IN TERTIARY INSTITUTIONS

<sup>1</sup>Audu Christopher, Sarki Sani, Dorothy Monday; <sup>2</sup>Sobowale, F. M. & <sup>3</sup>Saliu, R. M.

<sup>1</sup>Department of Integrated Science, School of Secondary Education, Science Programmes  
Kaduna State College of Education, Gidan Waya

<sup>2</sup>Federal University of technology, Minna,

<sup>3</sup>Niger State College of Education, Minna

Email: [auduchris@yahoo.com](mailto:auduchris@yahoo.com) Phone No: 07038626196

### 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 17<sup>th</sup> 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 (Zhai, 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 21<sup>st</sup>-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.

### **References**

- Alharbi, S. M., Elfeky, A. I. & Ahmed, E. S. (2022). The effect of e-collaborative learning environment on development of critical thinking and higher order thinking skills. *Journal of Positive School Psychology*, 6(6), 6848-6854.
- Chiu, T. K., Xia, Q., Zhou, X., Chai, C. S., & Cheng, M. (2023). Systematic literature review on opportunities, challenges, and future research recommendations of artificial intelligence in education. *Computers and Education: Artificial Intelligence*, 4, 100118.

- Dai, Y. (2023). Negotiation of epistemological understandings and teaching practices between primary teachers and scientists about artificial intelligence in professional development. *Research in Science Education*, 53(3), 577-591. <https://doi.org/10.1007/s11165-022-10072-8>.
- Gonzalez, A. J., Hollister, J. R., DeMara, R. F., Leigh, J., Lanman, B., Lee, S. Y., & Wilder, B. (2017). AI in informal science education: Bringing turing back to life to perform the turing test. *International Journal of Artificial Intelligence in Education*, 27, 353 -384. <https://doi.org/10.1007/s40593-017-0144-1>.
- Hermansyah, M., Najib, A., Farida, A., Sacipto, R., & Rintyarna, B. S. (2023). ArtificialIntelligence and ethics: Building an artificial intelligence system that ensures privacyand social justice. *International Journal of Science and Society*, 5(1), 154-168. <https://doi.org/10.54783/ijsoc.v5i1.644>.
- Hong, F., Dou, W., & Chen, S. (2022). Research on the impact of artificial intelligence on government public service quality. Paper presented at the 2<sup>nd</sup> International conference Public Management and Intelligent Society (PMIS).
- Hotmes, W., Bialik, M., & Fadel, C. (2019). Artificial Intelligence in Education: Promises and Implementations for Teaching and Learning. Center for Curriculum Redesign.
- Ibanez, M. B. & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. *Computer & Education*, 123, 109-123. <https://doi.org/10.1016.j.compedu.2018.05.002>.
- Kafyulilo, A., Fisser, P., & Voogt, J. (2015). Factors affecting teachers; continuation of technology use in teaching. *Education and Information Technologies*, 21(6), 1535 -1554. <https://doi.org/10.1007/s10639-01-9398-0>
- Luckin, R., Holmes, W., Griffiths, M., & Forcier, L. B. (2016). *Intelligence Unleashed: an Argument for AI in Education*. Pearson.
- Mahmoud, A. (2020). Artificial intelligence applications: An introduction to education development in the light of corona virus pandemic COVID 19 challenges. *International Journal of Research in Educational Sciences*, 3(4), 171-224.
- OECD (2020). *The Digital Transformation of Education Connecting Policy and Practice*. OECD Education Policy Perspectives.
- Park, J., Teo, T. W., Teo, A., Chang, J. Huang, J. S., & Koo, S. (2023). Integrating artificial intelligence into science lessons: Teachers' experiences and views. *International Journal of STEM Education*, 10(61), 46-54. <https://doi.org/10.1186/s40594-023-00454-3>

- Pima, J. (2019). Factors that motivate teachers to use ICT in teaching: A case of Kaliua District Secondary Schools in Tanzania. *International Journal of Education and Development Using ICT (IJEDICT)*, 15(1), 179-189.
- Popenici, S. A. D. & Kerr, S. (2017). Exploring the impact of artificial intelligence on teaching and learning in higher education. *Research and Practice in Technology Enhanced Learning*, 12(1), 22-23. <https://doi.org/10.1186/s41039-017-0062-8>
- Tang, K. S. & Cooper, G. (2024). The role of materiality in an era of generative artificial intelligence. *Science & Education*, 1-16. <https://doi.org/10.1007/s11191-024-00508> - UNESCO (2021). *AI and Education: Guidance for Policy-makers*. Paris: UNESCO.
- Wahyono, I.D., Fadlika, I., Asfani, K., Putranto, H., Hammad, J., & Sunarti (2019). New adaptive intelligence method for personalized adaptive laboratories. *International conference on electrical, electronics and information engineering (ICEEIE)*, pp. 196-200.
- Zawacki-Richter, O., Marin, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education- where are the educators? *International Journal of Educational Technology in Higher Education*, 16(1), 1-27.
- Zhai, X., He, P., & Krajcik, J. (2022). Applying machine learning to automatically assess scientific models. *Journal of Research in Science Teaching*, 59(10), 1765-1794. <https://doi.org/10.1002/tea.21773>.