



Leveraging Artificial Intelligence in Enhancing Worldwide Science, Technology, Engineering and Mathematics (STEM) Education

AYUA, Geoffrey Aondolumun¹

ayuageofrey@gmail.com

+2348069337213

KWAGH, Tertsea Caleb¹

kwaghcaleb@gmail.com

+234 816 179 5694

TERHEMBA, Wisdom Kwaghfan¹

kwatexwisdom@gmail.com

+2347063631099

ABAH, John Clement²

jonabah@gmail.com

+234 806 952 3916

OKANCHE, Samuel¹

sokanche-pg26@bsum.edu.ng

+2349164825455

OBIABO, Isaac Otache¹

obiaboisaac@gmail.com

+234 816 374 6181

¹Department of Science Education, Faculty of Education, Benue State University (now, Rev. Fr. Moses Orshio Adasu University) Makurdi, Nigeria

²Department of Integrated Science, Alvan Ikoku Federal University of Education, Owerri, Imo State, Nigeria

Abstract

Artificial intelligence is rapidly transforming education and presents opportunities for improving the quality, accessibility and inclusivity of STEM education around the globe. This conceptual paper examines the potential of AI to address persistent challenges in global STEM education. The paper explores major applications of AI in education including adaptive and personalized learning, intelligent tutoring systems, learning analytics, and teacher augmentation. Based on literature STEM education and educational technology an AI-STEM Global Enhancement Framework is proposed comprising of four core pillars: adaptive and personalized learning, intelligent tutoring and support, Smart assessment and analytics and teacher augmentation. This framework is anchored by the cross-cutting themes of equity, inclusivity, ethics, and global collaboration. The paper further examines challenges associated with AI integration in STEM education and suggests ways of mitigating these challenges. The paper concludes that AI should be actively integrated into STEM education and recommends a human-centred, ethical approach to its use in order to promote equitable and quality STEM education.

Keywords: Artificial Intelligence, STEM Education, Personalized Learning, Global Education.

Introduction

Education is an integral tool for societal building. According to Ayua et al. (2026a) Education is a fundamental instrument for human development, social stability, economic participation and global transformation. This explicates that an educated person can be functional suited in the society if it is wholistically implemented. It is a global phenomenon that can phased out boundaries. Global education refers to learning systems designed to overcome the barriers of geography, epistemology and institution to build competencies that allow engagement in interconnected global communities (Zaman, 2020). It therefore means that educational curricula maybe rich in accordance with the inspiration, needs or demands of the global society. Ayua and Taangahar (2024); Ayua (2019) posits



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that curriculum could always adapt to suit modern trends and paradigm shifts and STEM education is crucial for fostering the skills required for Sustainable Development Goals (SDGs) to be achieved by 2030 and beyond. This has become a world question whether technology can be a solution to STEM education, since the world has become a global village being interconnected through technology?

STEM is an approach to learning that connects four fields of science instead of teaching them separately. Science, which has to do with understanding the natural world through Biology, Chemistry, Physics and Earth Science. Technology, which is using scientific knowledge to create tools like Artificial Intelligence (AI) apps. Engineering which deals with designing and building solutions including civil, mechanical and electrical software. Mathematics that is the language for all of it, for example data analytics, logic and problem solving. These can be described as the centre for scientific discovery and innovation constituting a framework for global innovation and technological advancement. Fajrina and Ahda (2020) add that STEM education is an approach to learning that integrates elements of science, Technology, Engineering and Mathematics in the learning process and that each discipline is insufficient on its own as they cannot do without the other. However, the holistic integration of STEM education for 21st-century skills like critical and creative thinking skills, resilience, collaboration and problem-solving skills for everyday life is worrisome. Ayua (2019) confirms that one of the basic challenges in global STEM education is the limited resources available. Though the advancement of technology can be a solution to STEM education since it relies heavily on educational technology to create concepts, ideas and principles. One of these technologies is Artificial Intelligence (AI).

GenAI is AI which can create new stuff instead of just analysing or classifying old stuff. While Artificial intelligence (AI) is a complex evolution of technological innovation that is changing the global landscape (Terhemba et al. 2026; Ayua & Kwagh, 2026; Jomen et al., 2026). Its birth (invention) and rebirth (innovation) and it can be traced to a parallel advancement in STEM facilitated by STEM education. AI is a computer program that is able to learn from existing information and adapt behaviour to function efficiently in changing environments. These large language models can be able to show adaptive behaviour which is the hallmark of intelligence. Luckin et al (2016) asserts that AI is a computer system designed to perform tasks that typically require human intelligence such as visual perception, speech recognition, decision-making and language translation. It means that it can see and hear, understand and use language, create new things (GenAI), predict and decide, reason and solve problems, control and automate physical world, and amplify human work. Ayua et al (2026c) Kaplan and Haenlein (2019) see AI as systems with the ability to correctly interpret data, to learn from such data, and to use that knowledge to achieve specific goals and tasks. AI is able to adapt to the needs of learners and offer learning experiences that are learner-specific (Terhemba et al., 2026; Ayua et al., 2026b). This feature and application of AI in education makes it a valuable resource in Science, Technology, Engineering and Mathematics (STEM) education in providing personalized learning experiences that meet the specific needs of learners.

The fourth industrial revolution is characterized by the emergence of technologies, machines and computer programs such as artificial intelligence, robotics and the internet. This has intensified the need and global demand for STEM skills, knowledge and competencies. This is because modern technological innovations depend on scientific knowledge, logical reasoning, engineering skills and technological competency. It is therefore imperative to revolutionize and improve STEM education with techno-pedagogical shift like artificial intelligence.



Statement of the Problem

STEM education in ideal situation is supposed to make individuals skilful for action of no poverty, zero hunger, good health and wellbeing, quality education, clean water and sanitation, affordable and clean energy, decent work and economic growth, industry, innovation and infrastructure, reduced inequalities, sustainable cities and communities, responsible consumption and production, climate action, life below water, life on land, peace, justice and strong institutions, and partnership for the goals. However, there is a yawning gap between policy and practice for a wholistic implementation of STEM education. The fourth industrial revolution has significantly increased the global demand for knowledge and skills in STEM (Ayua, 2019; Ayua et al., 2022) and increasing application of artificial intelligence, machine programming and other emerging technologies require individuals who can think critically, creatively and apply scientific knowledge through technology and engineering. With this demand, the quality STEM education remains poor by pedagogy. This may include unequal access to STEM learning and inadequacy of proper teaching and learning resources especially in rural and disadvantaged communities (Aya et al., 2026a; Ayua et al., 2026d; Jaya et al., 2026). Also, the inadequacy of qualified and competent teachers in STEM related disciplines challenges the quality of knowledge and skills they are able to deliver. The unavailability of quality STEM teaching resources results in teacher centred teaching which promotes rote memorization. This creates a pressing need to rethink STEM teaching through techno-pedagogical approaches that promote active learning, equity, and global inclusivity in STEM education (Terhemba & Ayua, 2026).

Purpose of the Study

The purpose of this paper is to conceptualize the pedagogical use of AI in enhancing teaching, learning and assessment in STEM globally.

Significance of the Study

In line with Sustainable Development Goal 4, this paper will ensure access to inclusive and equitable quality education, promoting lifelong learning for all. It will also produce individuals equip for global competitiveness.

Scope of the Study

The paper is conceptual with worldwide focus drawing from both developed and developing contexts.

Conceptual Clarifications

STEM education in global context, Artificial intelligence in education and Rationale and discussed

STEM Education in Global Context

STEM education is an educational approach that integrates Science, Technology, Engineering and Mathematics. According to the United Nations Educational, Scientific and Cultural Organization ([UNESCO], 2026) STEM education is an interdisciplinary approach that equips learners with scientific knowledge, critical thinking, creativity, problem solving and innovation skills needed to address real-world challenges and participate effectively in a technology driven society. The global nature of STEM education is anchored on the premise that its knowledge and skills are globally relevant and the need for scientific, technological, engineering and mathematical knowledge is not limited to one country or region. STEM education is driven by worldwide advancements in knowledge and discovery.

Artificial Intelligence in Education

Artificial intelligence in education is an emerging interdisciplinary field that applies AI technologies in education to transform and promote the instructional and learning design, process and assessment (Chen et al., 2020). Artificial intelligence in education refers to the adoption of AI systems



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such as AI Tutors, adaptive learning systems, generative AI and learning analytics to support the education process such as teaching, learning and assessment. According to Albadarin et al. (2024) educational technology has evolved into AI systems with capacity to make significant advancements in learning, instructional methods as well as supporting administrative tasks. AI systems are capable of delivering learning experiences that meet individual learning needs (Jomen & Ayua, 2026).

The Rationale

Artificial intelligence is critical for scaling and delivering quality STEM education because it is capable of providing personalized instructions and quality learning resources that bridge the gap from abstract to concrete learning. AI can also deliver immediate feedback and support the assessment process of learners in STEM.

Literature Review/Theoretical Framework

Global trends of AI in Education, applications of AI in science, Technology, Engineering, and Mathematics, Benefits, Challenges and theoretical base are hereby reviewed.

Global Trends in AI in Education

Global trends in AI inclusion in education from 2020-2026 indicates a shift towards the widespread adoption of generative AI, AI Chatbots and personalized learning systems. AI can be used to personalize learning, support teachers in planning and delivering learning experiences and automate educational task such as grading assessment (Organization for Economic Co-operation and Development [OECD], 2025). As a result, global education systems are emphasizing digital literacy among teachers and students. However, there is call for a human-centred approach in the use and adoption of Generative AI in education (UNESCO, 2025).

Applications of AI in Science, Technology, Engineering and Mathematics

The ability of AI to perform numerous tasks has made it a useful tool with applications cutting across STEM disciplines. According to Terhemba and Ayua (2026) a vital merit of AI in STEM education is the ability to promote personalized learning, correct misconceptions, offer additional explanations and offer immediate feedback on student progress. These applications are vital in STEM fields. In Science AI is applied to analyse large amounts of data, scientific modelling, simulations and pattern recognition. In the field of technology, AI applications include robotics, software development, cyber-security and the development of intelligent data systems. Applications of AI in engineering are geared towards improving the efficiency and accuracy of engineering processes through system optimization, process automation, fault detection and predictive maintenance. The field of Mathematics has experienced improvement with AI through mathematical modelling, statistical analysis, coding and mathematical prediction models (Xu & Ouyang, 2022).

Benefits

The benefits and applications of AI in STEM education is yet under-explored. Improvements in AI programming directly translates to an improved educational experience as far as AI in concerned as represented in figure 1.

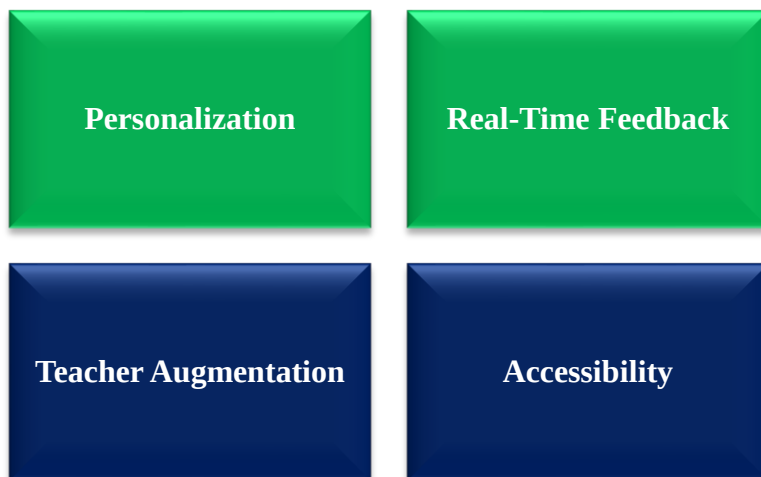


Figure 1: Schematic Representation of AI Benefits

As shown in Figure 1, AI systems are capable of diagnosing and accommodating different learning needs and abilities of students and to personalize learning experiences to meet individual student needs. This feature improves the quality and efficiency of STEM education by improving student participation and comprehension. AI systems maybe capable of delivering assessment feedback in real-time which helps to augment and support learning by promoting self-correction, increasing learner engagement and participation and strengthening understanding (Ayua et al., 2026b). The insufficiency of adequately trained and qualified teachers in STEM fields has been a major factor challenging the global quality of STEM education. AI systems can be used to augment and support teaching and learning. This is especially relevant where the student/teacher ratio is high. The unique capabilities of AI systems improve accessibility and creates inclusive opportunities for participation in STEM education by reducing barriers associated with geographical location, language, limited instructional resources and difference in students learning needs.

Challenges

While AI possess many benefits, in STEM education there are lingering challenges associated with its inclusion as shown in Figure 2:

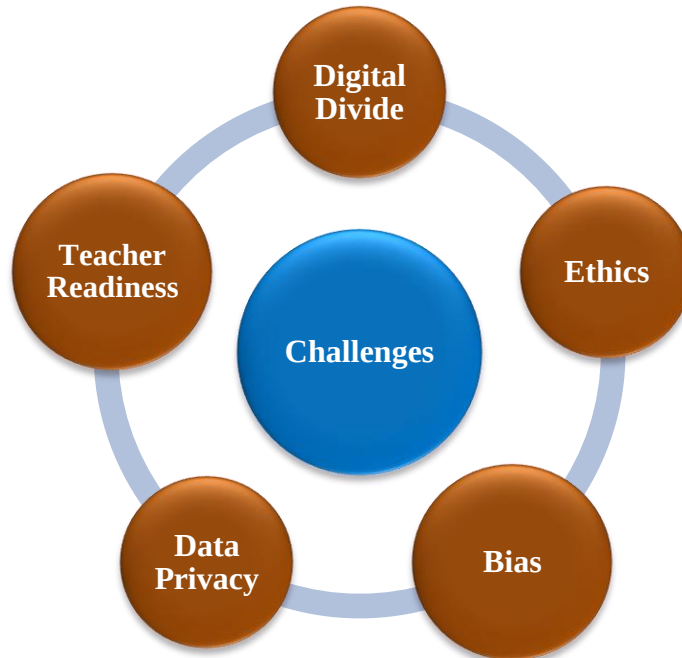


Figure 2: Challenges of AI in STEM Education

As presented in Figure 2, in developing countries like Nigeria among others, there is lack of proper access to digital devices as shown in Figure 2, reliable internet services, electricity and an inadequacy of the digital competency to operate AI systems especially in rural areas. This presents a challenge that confronts the successful and efficient implementation of AI in STEM education. The ethical concerns can limit AI inclusion in STEM education because issues surrounding transparency, academic integrity and responsible use may undermine trust, equity and the safe adoption of AI technologies. AI biased algorithms and data sets may reproduce existing inequalities such as gender-based inequality, resulting in unfair learning opportunities and educational experiences for certain group of students. The concerns bordering on the collection, storage, sharing and misuse of students' personal data and academic records can pose security risks and reduce trust in AI-supported learning. Teacher readiness can also hinder the effective and responsible inclusion of AI in STEM education when teachers lack the technological knowledge, pedagogical skills, and positive attitude towards AI supported learning.

Technological Pedagogical Content Knowledge (TPACK) Framework

The TPACK framework is a theoretical framework developed by Mishra and Koehler (2006). The framework explains the knowledge teachers need to integrate technology effectively into teaching. The framework consists of three forms of knowledge relevant for effective and efficient teaching as presented in Figure 3.

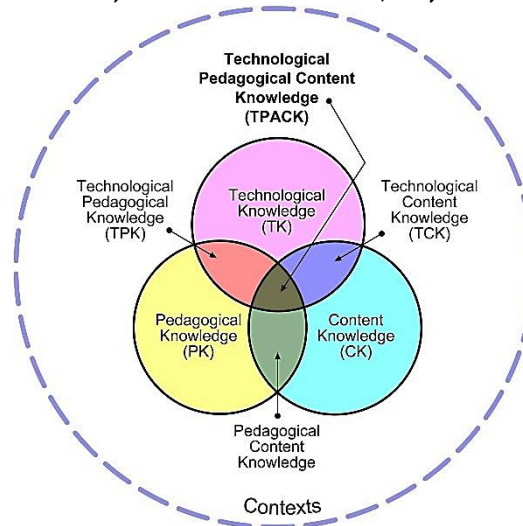


Figure 3: The Schematic Representation of TPACK Framework (Mishra & Koehler, 2006)

As show in Figure 3 Technology Knowledge (TK) is being knowledgeable about varieties of technological tools ranging from the basic, such as pencil and paper, to the most sophisticated, such as the world wide web, digital video, interactive white board and computer programs. Content Knowledge (CK) is the information about a specific topic that could be covered in a course or lesson. Educators therefore need background knowledge on the subjects they planned to cover and an understanding of how different types of knowledge are taught. Pedagogical Knowledge (PK) includes skill the in the classroom administration, students' evaluation, lesson planning and students naming. Pedagogical Content Knowledge (PCK) is the subjects' matter; experts gain for instructional purpose. Knowledge of both the subject matter and pedagogical practices necessary for effective teaching is PCK and its subject specific.

Technological Content Knowledge (TCK) is being familiar with the ways in which modern technologies can be used to create alternative representations of existing information. It means that educators can appreciate the power of technological tool such AI to change their students' approaches to learning withing a subject area. Technological Pedagogical Knowledge (TPK) can describe educators who are well versed in the way in which modern technology can be applied to the classroom and who recognise that these tools have the potential to alter traditional or conventional pedagogy. Technological Pedagogical Content Knowledge (TPACK) for effective teaching in any subject area, there can be a firm grasp of the educational content of technical tools at teacher's disposal. Teachers can have an intrinsic awareness of the relationship between the three pillars of knowledge, as evidenced by their utilization of successful pedagogical practice and technology resources in the STEM classroom for development of students' 21st-century skills (CK, PK, TK). The TPACK Framework provides a theoretical foundation for the integration of AI in STEM education by emphasizing the intersection of technological, content and pedagogical knowledge. This suggests that effective AI-supported STEM education requires teachers not only to have content and pedagogical knowledge but to be competent in handling technologies such as AI to support STEM instruction.

The AI-STEM Global Enhancement Framework

The Rationale for the framework, core pillars, cross-cutting themes and how the framework will enhance worldwide STEM education, are discussed as follows:

Rationale for the framework

The rapid development of AI systems has created new and endless possibilities for addressing persistent challenges in STEM education. The AI-STEM Global Enhancement Framework is for explaining how AI can be integrated into STEM education to improve learning outcomes and promote equitable access to quality STEM education across geographical boundaries. The framework conceptualizes AI integration around four pillars as shown in Figure 4. These core pillars of AI-STEM Global Enhancement framework are held together and operate within the cross-cutting principles of equity, inclusivity, ethics and global collaboration.

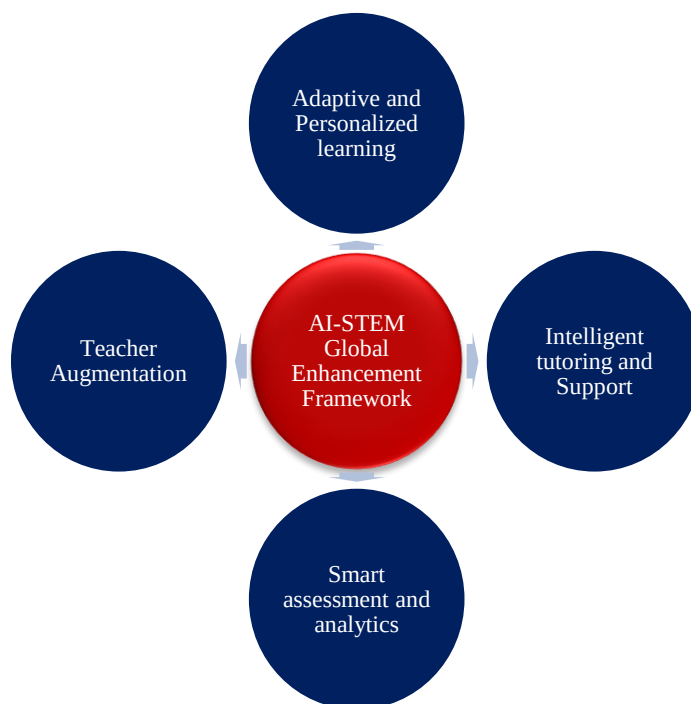


Figure 4: AI-

STEM Global Enhancement Framework

As show in Figure 4, adaptive and personalized learning for traditional classroom instruction often presents the same learning activities to all categories of students despite their difference in prior knowledge, learning pace, attitude and learning abilities. AI can address this pedagogical challenge by modifying learning experiences according to the individual characteristics, needs and learning abilities of learners (Ayua et al., 2026b; Parsakia, 2023). Within STEM education, adaptive AI systems can diagnose student learning needs and provide additional instruction, examples, simulations or practice activities. Learners who show higher order cognitive abilities can be exposed to more complex problems. This creates differentiated learning experiences for learners at their appropriate learning pace and moves STEM education towards students centred approach. Intelligent tutoring and support show that AI systems have the ability to provide learners with instructional assistance, explanations, guidance and feedback at any day and time during the learning process. AI based intelligent tutoring systems can simulate some functions traditionally performed by human teachers such as responding to questions. This pillar is important because STEM learning involves abstract concepts and complex problem-solving processes. This pillar emphasizes the ability of AI to augment teaching and learning at any point along the learning process.



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Smart assessment and analytics AI systems can be used for the collection, analysis and interpretation of learner assessment data to improve teaching and learning. AI systems can analyse student assessment and identify patterns of errors, misconceptions and provide immediate feedback. In STEM education, learners are prone to misconceptions on scientific principles or mathematical procedures. AI can diagnose learners through assessment to provide information about these misconceptions. The teacher can then modify instruction to provide an intervention. Teacher augmentation represents the use of AI to enhance and support teachers' instructional responsibilities. Teacher responsibilities such as lesson planning, preparation of instructional materials, assessment construction, and analysis of learner performance and academic development. In STEM education teachers may adopt AI to generate differentiated learning experiences, develop problem-solving activities, formulate assessment questions among others. It is important to emphasize that AI systems can only support and not replace the teacher (Terhemba & Ayua, 2026). Regarding the cross-cutting themes, equity can ensure that the benefits of AI supported STEM education are available to learners irrespective of geographical location, gender, socioeconomic status or disability. This framework will ensure equal access to STEM education. It will address existing biases and promote fairness across all categories of learners. Inclusivity may focus on designing AI-supported STEM learning activities that accommodate diverse needs, abilities and backgrounds of learners. AI can be utilized as a tool for enhancing the meaningful participation of learners despite the differences that exists between them. Ethics could do with the moral principles that guide the integration of AI in STEM education. The framework will be built on responsible use of AI to foster core academic and moral values of honesty, responsibility, integrity and data privacy (Ayua & Kwagh, 2026). The framework promotes a human centred approach to the use of AI where AI is used as a supportive tool and not to replace the teacher which borders on irresponsible use. Collaboration among educators, researchers, international organizations, educational institutions, governments and technology developers can facilitate the making of policies, the exchange of knowledge, pedagogical practices and digital resources. Such global collaboration is important for advancing equity in global STEM education in line with Sustainable Development Goal 4.

How the Framework could Enhance Worldwide STEM Education

The AI-STEM Global Enhancement Framework may enhance worldwide STEM education by providing an integrated approach through artificial intelligence which can improve the quality, accessibility, efficiency and inclusiveness of teaching and learning. Rather than viewing AI as a replacement for teachers, the framework can be a complementary technology that supports learners in learning and teachers in teaching. The framework promotes personalized STEM learning and expands access to quality all-round academic support. The framework also strengthens assessment and learning analytics and enhances teacher effectiveness. The work of teachers is often times very bulky for them to do and this can reduce teacher effectiveness and efficiency. AI systems can support teachers in carrying out several tasks at a time including lesson and assessment planning and sourcing for instructional materials. The framework provides an opportunity for access to quality STEM education across local, national and international boundaries.

Implications for Policy, Practice and Teacher Education

Curriculum integration, Teacher professional development for AI-Augmented pedagogy, Infrastructure and policy, and Global partnerships are discussed as presented in Figure 5.

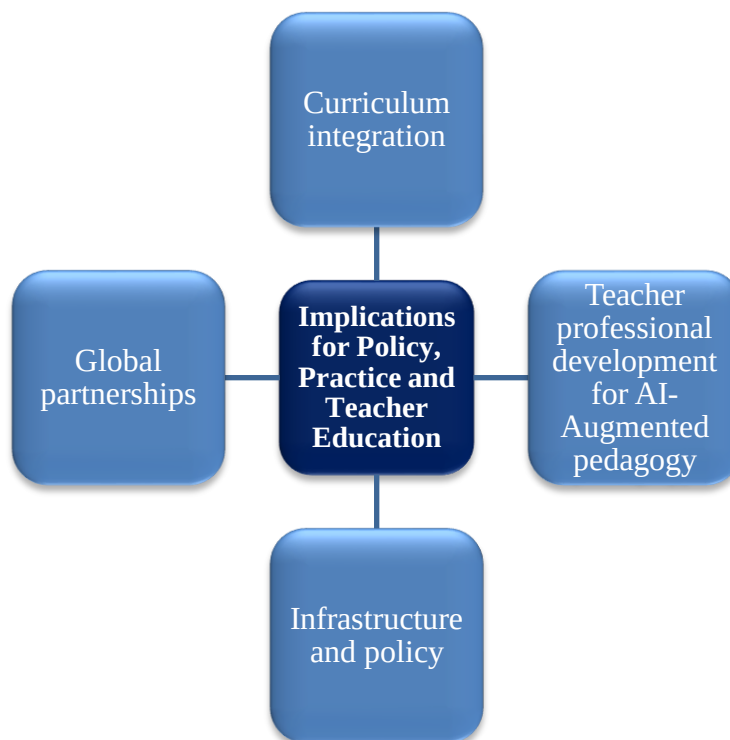


Figure 5: Schematic representation of Implications for Policy, Practice and Teacher Education

As presented in Figure 5, technological and digital skills are essential 21st-century skills. AI literacy can be integrated into STEM curriculum to equip learners with the knowledge and the required technological and digital skills in other to understand, use and responsibly interact with AI technologies. Teachers are the implementers of any curricular therefore, the successful implementation of AI in STEM education depends to a very large extent on teachers' competence in using AI technologies. Educational ministries and institutions may provide continuous professional development in technological and digital competency. Teacher educational programs can incorporate AI competency training alongside pedagogical and content knowledge training as well as the ethical use of these technologies. Adequate infrastructure is essential for successful integration of AI. This requires reliable internet services, electricity, digital devices, software programs and secure digital environments. Governments and educational institutions can invest adequate digital infrastructure in both rural and developing communities to ensure quality access to STEM education. Moreso, government can enact policies that guide responsible use of AI in STEM education. International collaboration could be established to enhance the adoption of AI in STEM education by allowing countries and educational institutions to share expertise knowledge, technological innovations and digital resources.

Mitigation Strategies AI-STEM Global Enhancement Framework Challenges

The full-scale implementation of the AI-STEM Global Enhancement Framework requires vast infrastructure such as reliable electricity, internet connectivity, digital devices, adaptive learning platforms and ICT facilities. These infrastructures mostly are unavailable especially in rural and developing areas, the cost implication of making them available is also very high. Difference in access to this infrastructure can create disparities between schools and learners in urban and rural regions. However, the low-cost digital tools can be a solution-based. AI integration can raise concerns



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bordering on ethical use, academic integrity, algorithmic bias and data security. These concerns can affect the efficiency of AI integration in STEM education. Therefore, Public-Private Partnership, Open Education Resource (OER) and Capacity building can help in effective practice of AI-STEM Global Enhancement Framework. Public-Private Partnerships can help governments, educational institutions and technology companies to work together and combine financial and technical resources. While the government provides policy direction and infrastructural support. Private organizations can provide other relevant support in terms of technological innovations and expertise. The Open Education Resource can reduce dependence on expensive educational material by making learning resources freely accessible for use, adaptation and distribution where permitted. AI systems can help adapt learning resources to learners needs, language and level. Teachers need training in technological and digital competence to ensure effective and ethical use of AI in STEM education.

Conclusion

Artificial Intelligence is an important component in modern day education with the potential to transform the teaching and learning of Science, Technology, Engineering and Mathematics. This submits that AI can contribute to enhancing the quality of STEM education by Supporting personalized learning and intelligent tutoring, Smart assessment, learning analytics and teacher augmentation through the AI-STEM Global Enhancement Framework. The AI-STEM Enhancement Framework provides an integrated model for understanding how AI can enhance STEM education globally through its four core pillars. The Framework is supported by the cross-cutting themes of equity, inclusivity, ethics and global collaboration. Despite its potential, the practice of the framework presents some challenges including inadequate infrastructure, algorithmic bias, ethical concerns among others. These challenges can be mitigated through government policies, teacher education programs and public-private partnership.

Call to Action

There is need for immediate action to improve the quality of global STEM education. The central challenge is how AI can be meaningfully and responsibly be integrated into teaching and learning. Concerned authorities and educational stakeholders therefore need to move towards practical practice.

Future Research Directions

Future research can move beyond conceptual discussions to empirical evidence on the effectiveness, sustainability and equity of AI-Supported STEM education.

Recommendations

The paper recommended among others that:

1. Policy Makers should develop clear national policies for AI in STEM education. These policies should address ethical concerns such as the responsible use of AI, data privacy and security, algorithmic bias, academic integrity and equity.
2. Governments and educational institutions should invest in the infrastructure required for effective AI integration. Reliable electricity, strong internet connection, digital devices and technical support particularly in rural and developing communities.
3. Teacher education institutions should integrate AI literacy and AI supported pedagogy into pre-service and in-service teacher education programs. Continuous professional development should equip STEM teachers with the technological, content and pedagogical competencies to effectively integrate AI in STEM instruction.



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4. Governments, educational institutions, technological organizations and international organizations should strengthen collaborative development to advance global education in STEM disciplines.

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