ARTIFICIAL INTELLIGENCE: KEY TO UNLOCKING PRODUCTIVITY IN STEAM EDUCATION IN NIGERIA

ADESINA Abiodun Ezekiel. & SHOTAYO Elizabeth Olusola
Biology and Integrated Science Education
Faculty of Science Education
Emmanuel Alayande University of Education, Oyo, Nigeria
Polytechnic Education and Allied Institutions Department,
Federal Ministry of Education HQ, Abuja, Nigeria.
draeadesina2015@gmail.com

Abstract
There is a general low productivity in STEAM education as either a disintegrated or integrated construct. Artificial Intelligence (AI) integration has significant implications for improving productivity and efficiency in STEAM (science, technology, engineering, arts, and mathematics) education in today's educational environment. This article explores the revolutionary potential of AI-driven approaches to upend traditional learning models and promote creativity in a range of STEAM education fields. Artificial Intelligence (AI) is revolutionizing STEAM education by tailoring content to individual needs and learning styles, enhancing comprehension and retention. AI-powered platforms provide adaptive learning experiences, automating administrative tasks and providing valuable insights into student progress. Virtual laboratories and simulations offer immersive learning experiences, fostering critical thinking and problem-solving skills. AI-powered tutoring systems offer personalized support, promoting self-directed learning. AI also fosters interdisciplinary collaboration and innovation, allowing students to explore creative expression and extract insights from complex datasets. Integrating artificial intelligence for STEAM education efficiency is premised on constructivists', behaviorists', connectivity' theories of learning and copious empirical evidence buttressed AI for STEAM education efficiency. However, widespread integration raises ethical and societal concerns, such as data privacy and equitable access to AI-driven resources. A holistic approach involving ethical guidelines, transparent algorithms, and inclusive pedagogical practices is needed to ensure AI technologies empower students and promote inclusive STEAM learning opportunities.

Keywords: STEAM education, Artificial intelligence, STEAM education efficiency.

Introduction

The evolution of STEAM education represents a significant approach to lay credence to the importance of inclusivity and interdisciplinarity in solving contemporary issues. As the world continues to tilt towards technology and innovation, pedagogical strategies that supports problem-solving, creativity, and critical thinking has become imperative (Xie, 2022; Tanty, et al., 2022). The integration of Artificial Intelligence (AI) into educational systems is one such move that has emerged as both a disruptive and transformational force poised to revolutionise learning methodologies (Bennett, 2023). In the Nigerian context, innovative and technological approaches to teaching can be said to be novel, hence the application of AI to STEAM education presents a huge opportunity to address the nation's educational woes (Hassan, 2022).

The significance of integrating AI in STEAM education to further deepen students learning experiences cannot be overstated going by the learning outcomes it brings about. Today's world

is characterized by technological advancements and digital transformations, therefore equipping students with AI literacy and computational thinking skills is of utmost importance (Abulibdeh et al., 2024). Integrating AI into STEAM disciplines enables educators to promote creativity, critical thinking and problem-solving skills in their recipients (Chang & Chou, 2020; Walter, 2024). These key contemporary skills inculcate in learners the ability to navigate the complexities of this digital age and contribute to a meaningful society.

In loose terms, AI refers to a situation whereby computer programmes are designed in such a way that they are positioned to discharge functions that ordinarily requires human intelligence (Moloi & Marwala, 2021; Bennett, 2023). In more specific terms. AI has been examined by different scholars from various dimensions depending on their disciplines and scope of study. Bennett (2023) described Artificial Intelligence as the process by which computers are made to study large amount of information or data with a view to identifying patterns and trends which can be adapted and applied in future decision making or resolutions. It is further described as stimulation of human intelligent processes by machines, encompasses a broad spectrum of technologies that enables machines to mimic cognitive functions such as learning, problem-solving and decision making. Put in a more technical language, AI in education relate to the use of sophisticated technologies such as machine learning and natural language processing to facilitate learning processes, making it more immersive, lively and personalized (Adesina, 2022; Araya & Scheidel, 2022; Chen, 2023).

The purpose of this paper is to provide a comprehensive overview of the current situation of AI integration in STEAM education within the Nigerian context, identifying existing initiatives, challenges and opportunities. Secondly this work seeks to marshal a roadmap for effectively integrating AI into Nigeria's educational framework considering factors such as curriculum design, teacher training, infrastructure and policy implications of such moves. Through this paper, contributions will be made to ongoing discourse on leveraging AI to enhance educational outcomes and fostering socio-economic development in Nigeria.

The Affordances of Integrating AI in STEAM Education

Scholars have established that the traditional system of conducting the knowledge system is hardly delivering on quality pedagogy irrespective of the field of endeavor (Stains, 2021; Ghafar, 2023). It is this inadequacy of the traditional method that has necessitated the application of AI in STEAM education especially in our peculiar situation with a rather low deployment of ICT in education. There are many factors which support the infusion of AI in STEAM education. Below are some of the most relevant in the Nigerian context:

a. **Increased Access to Education:** With sophisticated learning applications available via AI, educational contents can be delivered to the under-served such that learners located at different points can benefit from similar educational materials despite their locations.
b. **Learning at One's pace:** This quality of Technology-enhanced learning which also is amplified in AI, makes it a good pathway to foster individualized learning which experts have identified with huge results (Laak, 2024). The fact that AI positions every learner firmly in charge of their own learning boosts teaching and learning a great deal. This is hinged on the fact that each learner understands themselves and can adopt a style that best suits them facilitated by the Ubiquitous and flexible nature of AI (Moloi & Marwala, 2021). That is what AI does among other things to assist learners learn according to their peculiarities.

c. I**nteractivity:** Apart from the personalized learning that AI promotes, it is also able to create a situation whereby the learner communicates freely with AI-enabled tools and receives appropriate responses (Interactivity) (Bennett, 2023). Such automated responses enrich the quality of the learning process and go a long way to get the user hooked on learning thereby making a scholar out of every learner.
d. **Data-Driven Decisions:** One of the affordances of AI-powered platforms is in-built data-generation. The high point of this feature is that it is not only automatic but also seamless (Stains, 2021). AI makes it possible to study students' data and pinpoint where they have issues and proffer possible lasting solutions hence leading to improved learning experience.
e. **Adaptive Pedagogical Platforms:** With the aid of AI, computers can support learners having difficulty in any subject so to manage such difficulties thereby increasing students' retention rates especially in climes like Nigeria where the Out of School Syndrome is real.
f. **Teachers' Capacity Building and Professional Development**: AI provides teachers with training materials useful for their professional development with a view to supporting full technology integration in pedagogy.
g. **Language Support:** In this advent of AI, there is now no barrier to learning, not even language which used to be a potent hindrance to education and learning. Translation features available on AI applications is gradually dissolving Language-associated learning difficulties (Moloi & Marwala, 2021).
h. **Fostering 21st Century Skills**: Contemporary skills such as critical thinking, problem solving, analytical, creativity and innovative skills have been made possible and easier with AI
i. **Development of Requisite Skills in the 21st century world of work:** Learners in this contemporary world must be ready to acquire 21 century skills if they are to find relevance in today's world of work (Laak, 2024). AI has been seen to support the development of such skills.
j. **Industrial experience:** Students of higher Educational Institutions are by virtue of the affordances available in AI exposed to experiences that were not available to students within the four walls of the classrooms. Students are also able to gain from simulations which give same industrial exposure as if they are physically present in industrial environments.

Examples of AI integration in STEAM education

The following are instances of AI application in STEAM education:

a. AI-enhanced Grading and Feedback System: AI makes it possible for educators to take full advantage of the automated grading and feedback systems. This saves a lot of time and resources which could have gone into manually sorting these things coupled with the errors such manual process are prone to.
b. Career Choice Assistance: This has been of immense benefit to students in helping to study trends in student's past records and identify areas of strengths and interests hence provide quality guidance to students and learners alike.
c. Collaborative Learning Platforms: These are AI-facilitated online environments made to promote groups of learners coming together to learn, brainstorm, share resources, organize tasks and track progress of such tasks (Laak, 2024). Examples of these include

but not limited to the famous Zoom, Google classroom, Learning Management Systems and Microsoft teams.

d. Virtual laboratories: This has presented students with extensive opportunities to simulate experiments and investigations in a well-controlled environment. Virtual laboratories are safe since learners are not exposed to the possible dangers obtainable in physical laboratories (Araya & Scheidel, 2022).
e. Intelligent Tutoring Systems: Intelligent Tutoring Systems enables students to access instructions meant specifically for them to help in their studies in real time. These systems assume the role of a lecturer or teacher in its mode of operations
f. VEX Robotics: This is a platform where students can pick up knowledge about Robotics and Engineering and Computer science in a project-based learning mode (Bennett, 2023). VEX Robotics possesses some vital aspects such as curriculum and Resources, platforms and programming language (for-instance: python and C++)

Artificial Intelligent Virtual artist (AIVA): finds relevance in teaching music students' learners are exposed to the integration of technology in music. It displays a whole lot of possibilities via AI applications.

PhET Interactive Simulations: enables a wide range of topics be taught in a near-real life situation as scenarios are brought as close as possible to real life situations in simulations.

Smart Contents: help to create custom made content for each learner. This AI tool is easily adapted to each student's learning pace and style, such that no learner is left behind.

Challenges and concerns with AI integration in STEAM education

AI is a watershed in the history of education globally, there are several issues that are of concerns to educators and users of AI. Some of these challenges as they relate to the knowledge process are as follows:

Little or No Teacher Training: Though AI and its affordances emerged a while ago, evidence abound to the fact that many teachers and lecturers are not so vast in its use (Moloi & Marwala, 2021). Hence, educators do not have the requisite expertise to integrate AI into STEAM teaching.

Data Privacy: Providing adequate security and privacy for the huge amount of data obtained by virtue of AI operations via various platforms is still a course for concern for educators. Data privacy and security is one that must be taken seriously to prevent situations where data given on trust falls into wrong hands (Walter, 2024). All efforts must be on deck to forestall possible abuse or unethical use of students' data.

Equity and Accessibility: There is a general belief that the integration of AI in STEAM education would further widen the gap between the haves and the have nots as regards exposure to technology (Hassan, 2022). As many learners as possible should be brought into the technology-inclusion net and not pushed out.

Cost Issues are yet another area of concern. AI platforms/applications are still on the high side in terms of cost (Chang & Chou, 2020). This factor has been identified as one that could potentially increase the population of technology-iliterates in the country.

Erosion of Creative reasoning: One major concern brought about using AI is the addictive use of it which can be a threat to creativity and critical thinking. AI applications provide ready answers hence encourages over-dependence and is

gradually eroding the power of critical reasoning as well as problem solving among educators (Abulibdeh, Zaidan , & Abulibdeh, 2024; Xie, 2022).

Strategies for successful AI integration in STEAM education

Providing training and support for educators

Artificial intelligence (AI) integration into STEAM education can significantly improve learning experiences and prepare students for the future job market. To ensure successful integration, educators need to understand AI concepts and applications, such as machine learning algorithms, natural language processing, computer vision, and robotics. They should also be trained on pedagogical strategies that use AI tools to facilitate STEAM learning, such as incorporating AI-based adaptive learning platforms (Adesina, 2024). They should also be supported in navigating ethical and social implications of AI integration, such as data privacy, algorithmic bias, and the impact of automation on the workforce. Access to resources and tools, such as AI software platforms and online courses, is crucial. Establishing collaborative learning communities can facilitate knowledge sharing and peer support among educators.

Ensuring ethical and unbiased AI algorithms

Ethical and unbiased AI algorithms are essential for successful integration into STEAM education. This involves incorporating ethical considerations into the curriculum, promoting diversity in AI development, fostering transparency in algorithmic decision-making, implementing continuous monitoring and evaluation mechanisms, and engaging stakeholders in ethical discussions. By incorporating ethical AI education, promoting diversity, and ensuring fairness, educators can foster responsible AI use among students. By ensuring diverse representation in AI development teams, educators can create more inclusive and equitable AI algorithms. Continuous monitoring and evaluation of AI algorithms can help identify and mitigate biases over time. Engaging diverse perspectives in decision-making processes fosters a culture of ethical awareness and accountability. Heredia-Carroza and Stoica (2023) in the study that explores AI integration in higher education emphasized the need for strategic planning, ethical considerations, and balancing technology with traditional approaches to preserve academic integrity and design effective policies. Overall, ensuring ethical and unbiased AI algorithms is a foundational strategy for successful STEAM education.

Prioritizing accessibility and equity

The integration of AI into STEAM education is crucial for creating an inclusive learning environment that fosters innovation and creativity. Strategies include Universal Design for Learning (UDL), customization and personalization, open educational resources (OER), collaborative learning platforms, ethical AI design, and professional development. UDL ensures AI-powered tools are accessible to diverse learners, including those with disabilities. Personalization and customization can address individual differences in students' abilities, interests, and preferences, enhancing engagement and promoting equitable access to educational opportunities. Open educational resources can reduce barriers to accessing quality materials, while AI-powered collaborative learning platforms promote collaboration and equity. Ethical AI design principles, such as transparency, fairness, and accountability, are essential to prevent biases and inequities in education.

Collaboration between stakeholders in education and AI industries

The integration of AI into STEAM education requires collaboration between education stakeholders and the AI industry. This involves conducting needs assessments and co-design

processes, collaborating on professional development and training programs, establishing research and development partnerships, ensuring data sharing and privacy protocols, addressing equity and inclusion initiatives, and promoting policy advocacy and governance. These strategies help tailor AI technologies to meet the specific needs of STEAM education, foster innovation, protect student data, and ensure equitable access to AI technologies. By fostering collaboration, educators can harness the potential of AI to enhance teaching and learning experiences while addressing unique challenges and opportunities.

Theoretical Bases for Enhancing STEAM Education with AI

AI-enhanced STEAM (science, technology, engineering, arts, and mathematics) education entails using a variety of theoretical frameworks to guide the creation, use, and assessment of AI-powered educational initiatives. The following recent citations emphasize the theoretical frameworks that support the incorporation of artificial intelligence (AI) into STEAM education:

Socio-cultural Theory and Constructivism: - Constructivism places a strong emphasis on the value of students actively creating their own conceptual understanding via practical applications and interpersonal interactions (Jonassen, 1994). This is furthered by socio-cultural theory, which emphasizes how social interactions and cultural environments influence learning (Vygotsky, 1978). By offering interactive simulations, collaborative learning settings, and adaptive feedback mechanisms, AI technology can support socio-cultural and constructivist approaches (Mavrikis & Gutierrez-Santos, 2016).

Cognitive Load Theory: This theory looks at how learning outcomes are affected by the cognitive demands of learning tasks (Sweller et al., 2011). By dynamically altering task complexity, offering scaffolding, and presenting material in ways that correspond with learners' cognitive capacities and experience, AI-powered adaptive learning systems can maximize cognitive load (Koedinger et al., 2012).

Self-Determination Theory: - According to Deci & Ryan (2000), self-determination theory (SDT) highlights the value of autonomy, competence, and relatedness in fostering intrinsic motivation and learning engagement. By providing individualized learning opportunities that enable students to explore their interests, gain mastery, and establish connections with peers and mentors, AI technologies can enhance SDT (Reeves et al., 2020).

Universal Design for Learning (UDL): UDL stands for Universal Design for Learning. According to Rose and Meyer (2002), UDL offers a framework for creating adaptable learning environments that satisfy the requirements and preferences of various learners. By providing many channels for representation, expression, and interaction, AI-enhanced instructional resources can uphold UDL principles and advance fairness and accessibility in STEAM education (Bouck et al., 2021).

The theory of complexity: The theory of complexity holds that learning is a dynamic and intricate process that arises from the interactions of adaptive systems (Davis & Sumara, 2006). By analyzing vast datasets, recreating dynamic processes, and offering real-time feedback, artificial intelligence (AI) can support learning in complex systems by allowing students to investigate and comprehend emergent characteristics and patterns (Blikstein, 2013).

Connectivism is another learning theory developed by George Siemens and Stephen Downes, offers a framework for integrating Artificial Intelligence (AI) into STEAM education. Connectivism emphasizes the role of technology and networks in the learning process, suggesting

that learning occurs across a network of connections. By nurturing and maintaining these connections, continuous knowledge acquisition is facilitated, aligning well with the dynamic and interdisciplinary nature of STEAM education.

Several connectivity's principles can significantly enhance STEAM education when coupled with AI. These include facilitating networked learning environments, creating personalized learning pathways, providing real-time feedback and adaptation, encouraging interdisciplinary connections, enhancing collaboration and communication, and continuously updating educational content.

Practical applications of AI in STEAM education include AI tutors and learning assistants, intelligent content recommendation systems, virtual labs and simulations, and collaborative platforms like Slack or Microsoft Teams. These tools can provide personalized instruction, support students' learning styles, and provide a diverse and rich learning experience. By leveraging AI's capabilities to foster networked learning, provide real-time feedback, and facilitate interdisciplinary connections, educators can enhance the effectiveness and relevance of STEAM education in the digital age, preparing students to thrive in an increasingly complex and connected world (Adesina, 2024).

Empirical Bases for Enhancing STEAM Education with AI.

Research shows that integrating AI in STEAM education can enhance learning experiences and emotional responses. AI analytics, intelligent technology, affective computing, and chatbot-based tutoring systems can develop AI-Thinking skills, foster interdisciplinary learning, and enhance learning attitudes (Mavrikis & Gutierrez-Santos, 2016; Ren & Zhang, 2021; Sun e al., 2019). A comprehensive research framework incorporating cognitive, affective, and psychomotor domains can also help. Hands-on educational modules can make AI and robotics more accessible and engaging.

AI-powered STEAM education can improve student outcomes by enhancing adaptive learning systems, personalized learning experiences, data-driven decision making, Intelligent Tutoring Systems (ITS), collaborative learning environments, and real-world applications and simulations. Studies have shown that AI-based adaptive learning systems improve mathematics achievement, personalized learning experiences enhance student engagement and motivation, and AI-powered ITS provide individualized instruction and scaffolding (Gong e al., 2021; McQuiggan e al., 2020; Wang e al., 2020). AI-supported collaborative learning environments promote peer interaction and knowledge sharing, while AI-powered simulations and real-world applications provide authentic learning experiences. By leveraging empirical evidence, educators can make informed decisions about integrating AI technologies into STEAM education, enhancing student learning outcomes and fostering the development of 21st-century skills.

Chang and Chou (2019) highlighted the transformative impact of artificial intelligence in STEAM education, stressing its use in content recording and feedback analysis, and its importance in improving students' higher-order thinking, creativity, problem-solving abilities, and AI literacy. The study by Ouyang and Xu (2022) reviewed AI technologies in STEM education from 2011 to 2021, identifying six categories and their effects. The research challenges the integration of diverse AI techniques in a complex educational system. The study suggests further exploration of AI's potential to enhance STEM education, highlighting the need for further research.

Linn et al. (2023) in Zhai et al. (2023) studied Artificial intelligence (AI) as an emerging technology, is increasingly being used in STEM education and research. It can address challenging

problems in STEM education, such as supporting students to meet 21st-century visions for science learning. Policy documents like the U.S. Framework for K-12 Science Education, Germany, Finland, and the PISA framework emphasize the importance of developing proficiency in using ideas to solve complex problems and explain everyday phenomena.

Siti et al.'s 2024 study on artificial intelligence in STEM education found a strong correlation, with conference papers being the most common source. The US contributed most, followed by China and Hong Kong. Aljuaid (2024) systematic review of AI's impact on academic writing in higher education found that while AI improves grammar and style, it doesn't replace traditional courses that teach critical thinking, research, citation, argumentation, creativity, originality, and ethics.

Conclusion

Artificial Intelligence (AI) can significantly improve STEAM education in Nigeria by addressing challenges like teacher shortages, personalized learning, and limited access to resources. AI-driven tools can provide personalized learning experiences, automate administrative tasks, and provide valuable insights into student performance. AI can also facilitate remote learning, bridging educational disparities. However, successful implementation requires adequate infrastructure, training for educators, and ethical considerations like data privacy and algorithmic bias. By addressing these challenges and fostering a supportive ecosystem, Nigeria can harness the full potential of AI to transform its educational landscape and equip students with future skills.

Recommendations

To effectively integrate Artificial Intelligence (AI) into STEAM education in Nigeria, strategic suggestions include expanding internet connectivity, providing digital devices, enhancing teacher training and professional development, integrating AI into the curriculum, developing national AI policies, fostering public-private partnerships, investing in research and development, addressing the digital divide, and supporting underserved areas. Additionally, Nigeria should invest in Research and Development (R&D), pilot programs, and support for remote and underserved areas to ensure equal access to AI-powered educational resources. Monitoring and evaluation of AI integration should establish metrics to assess its impact on educational outcomes and productivity, and create feedback mechanisms for teachers, students, and parents to understand its effectiveness and make necessary adjustments. By implementing these suggestions, Nigeria can create a conducive environment for successful AI integration in STEAM education.

References

Abulibdeh, A., Zaidan , E., & Abulibdeh, R. (2024). Navigating the confluence of artificial intelligence and education for sustainable development in the era of industry 4.0: Challenges, opportunities, and ethical dimensions. *Journal Cleaner Energy, 437*. doi:https://doi.org/10.1016/j.jclepro.2023.140527

Adesina, A. E. (2022). *Teacher education, ict and artificial intelligence in the 21st century*. In P. I. Farayola, R. A. Foyewa, S. A. Salman, O. O. Adeboye, F. A. Ajasa, I. O. Mustapha, R. A. Raji. Teacher education and 21st century global contemporary issues (pp. 181-191). Ibadan: Graceville Publishers

Adesina, A. E. (2024). Artificial intelligence and steam curriculum development. In P. A. Okebukola (Ed.) Handbook on Artificial Intelligence and Quality Higher Education. Volume 1, AI in Enhancing Teaching/Learning, Research and Community Service in Higher Education. Book in Honour of Abubakar Adamu Rasheed, pp.461-470.

Araya, R., & Scheidel, W. (2022). AI in Education. *Crossroads*.Journals/crossroads-1q36a0gm

Barron, B., Cayton-Hodges, G., Bofferding, L., Copple, B., Darling-Hammond, L., & Munoz, C. (2015). Learning ecologies for technological fluency: *Gender and experience differences. Computers & Education,* 82, 14-33.

Bennett, R. (2023). *Artificial intelligence and generative ai made easy: A beginner's guide to mastering chatgpt, google bard, and tomorrow's Tech Today.* https://www.artificial-intelligence-generative-made-easy/dp/B0CN58RCCS

Blikstein, P., Worsley, M., Piech, C., Sahami, M., Cooper, S., & Koller, D. (2020). AI for education: Open-ended learning environments. *Journal of Artificial Intelligence in Education,* 30(2), 211-218.

Bouck, E. C., Lo, Y. Y., Flanagan, S., & Joshi, G. (2021). Teacher perceptions of UDL and students with disabilities in inclusive STEAM settings. *Journal of Special Education Technology,* 36(1), 36-45.

Chang, Y., & Chou, C. (2020). Integrating artificial intelligence into steam education. *Communications in Computer and Information Science, 12-27.* doi:https://doi.org/10.1007/978-981-15-6113-9_52

Chen, M. H. (2023). The widespread application of artificial intelligence in education necessitates critical analyses. *Science insights education frontiers, 6*(2), 2475-2486. doi:https://www.doi.org/10.15354/sief.23.co081

Chen, X., Liu, B., & Su, Y. (2021). Improving real-time teaching efficiency with AI-assisted educational decision-making: A study on interactive instruction and feedback. *Educational Technology Research and Developme*nt, 69(4), 2063-2083.

Diakopoulos, N. (2020). Automating the news: How algorithms are rewriting the media. Harvard University Press.

European Commission. (2019). Ethics guidelines for trustworthy AI. Retrieved from https://ec.europa.eu/digital-single-market/en/news/ethics-guidelines-trustworthy-ai

European Commission. (2019). *Policy options and roadmap for artificial intelligence in education*. Publications Office of the European Union.

Fitzpatrick, C., Tzovaras, D., & Heckman, N. (2011). Collaborative design as a way to foster a co-creative dialogue between developers and users of technology-rich learning environments. *Interactive Learning Environments,* 19(5), 451-467.

Ghafar, Z. N. (2023). The teacher-centered and the student-centered: A comparison of two approaches. *International Journal of Arts and Humanities, 1*(1). doi::10.61424/ijah.v1i1.7

Gong, Y., Xie, H., & Su, Y. (2021). The effectiveness of an artificial intelligence adaptive learning system in mathematics education: A quasi-experimental study. *Educational Technology Research and Development,* 69(3), 1183-1205.

Hassan, Y. (2022). Governing algorithms from the South: A case study of AI development in Africa. *Springer Link, 38,* 1429–1442.

Heredia-Carroza J. & Stoica, R. (2023). Artificial intelligence in higher education. a literature review. *Journal of Public Administration, Finance and Law*, 30, 97-115.https://doi.org/10.47743/jopafl-2

Jobin, A., Ienca, M., & Vayena, E. (2019). The global landscape of AI ethics guidelines. *Nature Machine Intelligenc*e, 1(9), 389-399.

Jonassen, D. H. (1994). Thinking technology: Toward a constructivist design model. *Educational Technology*, 34(4), 34-37.

Jung, Y., Park, J., & Lee, J. (2020). Educator AI literacy and pedagogical skills: implications for artificial intelligence in education. *Educational Technology & Society*, 23(3), 20–33.

Karsenti, T., & Bugmann, J. (2019). *AI in Education: Challenges and Opportunities for Professional Development. In AI in Education: Innovations for Pedagogy, Teaching and Learning* (pp. 3–14). US: Springer.

Ke, F., Im, T., & Renshaw, T. L. (2020). A meta-analysis of the effectiveness of intelligent tutoring systems on K–12 mathematics and science learning. *Educational Technology Research and Development*, 68(6), 2789-2819.

Koedinger, K. R., Stamper, J. C., McLaughlin, E. A., & Nixon, T. (2012). Using data-driven discovery of better student models to improve student learning. In Proceedings of the 5th International Conference on Educational Data Mining (pp. 92-99).

Koedinger, K. R., Stamper, J. C., McLaughlin, E. A., & Nixon, T. (2012). *Using data-driven discovery of better student models to improve student learning.* In Proceedings of the 5th International Conference on Educational Data Mining (pp. 92-99).

Laak, K. (2024). *AI and personalized learning: bridging the gap with modern educational goals*. https://arxiv.org/html/2404.02798v1

Mavrikis, M., & Gutierrez-Santos, S. (2016). Towards learning analytics for the design of digital support for exploratory learning practices. *Computers & Education*, 102, 202-216.

McQuiggan, S., Robelia, B., & Hughes, J. (2020). Advancing equity and inclusion with artificial intelligence: Opportunities for research and practice in educational technology. *Educational Technology Research and Development*, 68(5), 2373-2392.

Mittelstadt, B. D., Allo, P., Taddeo, M., Wachter, S., & Floridi, L. (2019). The ethics of algorithms: mapping the debate. *Big Data & Society*, 6(2), 1-21.

Moloi, T., & Marwala, T. (2021). A high-level overview of artificial intelligence: Historical overview and emerging developments. In *Artificial Intelligence and the Changing Nature of Corporations. Future of Business and Finance.* 978-3-030-76312-1 ISBN: Springer, Cham. doi: 10.1007/978-3-030-76313-8_2

Reeves, T. C., Grosseck, G., Schrape, J. L., & Ainsworth, S. (2020). Understanding student engagement with an AI-supported adaptive learning system: A mixed methods analysis. *Educational Technology Research and Development*, 68(6), 3311-3331.

Ren, J., Su, Y., & Zhang, X. (2021). The application of virtual reality based on AI in the teaching of engineering courses: A case study of structure mechanics. *Educational Technology Research and Development*, 69(2), 911-927.

Stains, M. (2021). *Teacher-centered systemic reform (TCSR) model*. Accelerating Systemic Change Network: https://ascnhighered.org/ASCN/change_theories/collection/tcsr.html

Sun, Y., Zhang, M., & Gong, Y. (2019). Can artificial intelligence enhance collaborative learning? A quasi-experiment study. *Computers & Education*, 142, 103649.

Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive load theory*. US: Springer.

Tanty, H., Fernando, C., Valencia, J., & Justin, V. (2022). Critical thinking and problem solving among students. *Business Economic, Communication and Social Sciences Journal*.

https://www.journals/business-economic-communication-and-social-sciences-journal-gwa7xpzk

Walter, Y. (2024). Embracing the future of artificial intelligence in the classroom: the relevance of AI literacy, prompt engineering, and critical thinking in modern education. *International Journal of Educational Technology in Higher Education, 21*(15). doi:https://doi.org/10.1186/s41239-024-00448-3

Van Horn, J. D., Kurashige, J., & Glocker, B. (2019). Data privacy in the era of digital medical images. *Nature Medicine,* 25(1), 37-43.

Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes. Harvard University Press.

Wang, Y., Liu, R., & Wang, Q. (2020). The effect of personalized learning guidance supported by an intelligent tutoring system on the self-efficacy and interest of students in computer science learning. *Educational Technology Research and Develo*pment, 68(6), 3029-3046.

Xie, B. (2022). Critical thinking and problem solving. *The ICERI*, (pp. 4073-4077). doi:10.21125/iceri.2022.0986

Yoon, S. A., Anderson, E., Koehler-Yom, J., Klopfer, E., Sheldon, J., Wendel, D., ... & Schoenfeld, I. (2019). Designing and implementing ai integrated classrooms: promises, challenges, and implications for teacher education. *TechTrends,* 63(6), 743–752.