NIU Journal of Educational Research Copyright©2024
Nexus International University ISSN: *3007-1844;* 10(2): 59-72

Artificial Intelligence and Machine Learning in enhancing Science Learning Experiences: Exploring Possibilities and Concerns

CLARA DUMEBI MOEMEKE
University of Delta, Agbor, Nigeria

Abstract. The advent of Artificial Intelligence and Machine Learning has made remarkable impart in all sectors of human activities. In the field of science education, integrating AI and ML have opened new dimensions for improving learning experiences by offering individualized learning, adaptive feedback, innovative pedagogues and data-driven insights that enable science students and teachers to engage with science content and materials in interactive and personalized ways. AI-tools such as virtual tutors, intelligent simulations, and algorithms analyze students' learning patterns, generate context-specific assistance that deepens conceptual understanding of science concepts and problem-solving skills of students. This paper reviews the benefits AI and ML in fostering inquiry-based learning, creating immersive virtual labs where students can conduct experiments in simulated environments, thus helping to mitigate the challenges often posed by poor equipment in physical science laboratories especially in low economies. It highlights how AI tools can improve accessibility to otherwise complex topics, facilitate effective continuous assessment of students' learning outcome and improve students' motivation to learn science through instant feedback. However, the integration of AI and ML in science education raises some concerns. The issue of privacy, over-dependence on technology, perpetrating educational inequalities due to differentials in access are critical challenges requiring mitigation. Ethical implications of using biased data and inability of AI to enhance critical thinking and creativity compared to human teachers are instructive. A balance in human and technology integration in science education is suggested.

Keywords: Artificial intelligence; Machine learning; SCIENCE education; science learning; learning experiences; Educational technology

1. Introduction

The rapid advancement of technology has profoundly influenced all landscapes especially education. From traditional classrooms to digital learning environments, technology has emerged as a transformative force, reshaping how humans perceive, impart, acquire, and apply knowledge in virtually all domains (Liando & Tatipang, 2024; Haidir, 2023; Nykyporets et al., 2023; Cheung et al.,2021; Groff, 2013). This evolution has ushered in a new era in education characterized by enhanced accessibility, engagement, and customization (Malik, 2023; Bondac & Hrestic 2023; Crawford, 2017). The growing role of technology in education and technology of education can be observed across various dimensions. Digital tools, ranging from interactive learning platforms to virtual simulations, have become integral components of modern pedagogical approaches (Kiong, 2023; Li, 2023; Haleem et al., 2022; Guaña-Moya et al., 2022; Asad et al., 2021; Makarova & Makarova, 2018). These tools facilitate dynamic and immersive learning experiences that cater to diverse learning styles, engaging students in ways that textbooks and lectures alone cannot achieve. The availability of online resources and open educational materials have democratized education, breaking down geographical barriers and expanding learning opportunities beyond traditional classroom settings. This accessibility is particularly important in bridging educational gaps and promoting lifelong learning, as learners of all ages can access a wealth of information at their own pace and convenience (Luo, 2022; Inegbedion, 2022;

Condruzbacescu, 2020; Nobre, 2020; Faridi & Ebad, 2018; Ritella, 2017). Of note is the impact of collaborative technologies which have transformed the way students interact with peers and educators. Virtual classrooms, discussion forums, and collaborative document editing enable learners to seamlessly communicate and share knowledge, fostering a sense of community in both physical, virtual and even remote learning environments.

The rise of technology in education, however, comes with its set of challenges and considerations. Prominent among these are ensuring equitable access to technology, addressing privacy concerns, and striking a balance between screen time and face-to-face interaction (Joshi, 2023; Jiang, 2023; Castelli, & Sarvary, 2021; Franks, 2020; Anshari,et al., 2017). These are complex issues educators and policymakers often encounter and grapple with while using technology in the field of science education. In harnessing the beneficial qualities of integrating technology in education, science educators need to critically understand and empower learners to thrive in an increasingly digital world.

The science education domain is undergoing a profound transformation with the integration of cutting-edge technologies as in industries and human interaction. Their application within the realm of science education opens up new dimension for enhancing learning experiences, comprehension of complex concepts, and overall engagement among science learners (Rahmat, et al., 2023; Patero, 2023; Struyf et al., 2019). Such technological frontier that are currently redefining science teaching and learning are Artificial Intelligence (AI) and Machine Learning (ML). AI and ML, once confined to the realm of science fiction, have swiftly become tangible realities, ingrained in our daily lives through virtual assistants, recommendation systems, and autonomous vehicles (Bilow, 2020). Within the context of education, they offer a gateway to personalized, dynamic, and immersive learning experiences that are tailored to the individual needs and preferences of students. In science education, where abstract and intricate concepts often pose challenges to traditional pedagogical methods, the integration of AI and ML offers a novel approach to bridging comprehension gaps.

The role of AI in facilitating a customized learning journey that ensures no student is left behind by adapting to the pace and style of individual learners has been acknowledged (Aggarwal et al., 2023; Jian, 2023). Also, the utilization of AI-powered simulations and virtual workrooms and laboratories brings intricate scientific phenomena to life, enabling students to experiment, explore, and learn through hands-on experiences that were once confined to physical laboratories. This augmentation of learning encounters has the potential to transcend the limitations of physical resources and logistical constraints.

However, as with any transformative advancement, the integration of AI and ML in science education comes with certain complexities and considerations which if not professionally mitigated may hamper the efficacious benefits of the innovation. Ethical concerns, such as data privacy and algorithmic bias require meticulous attention to ensure equitable and fair learning opportunities for all students. The fine balance between human interaction and technological assistance must be carefully navigated to avoid diminishing the critical thinking skills that is at the heart of scientific inquiry and scientific reasoning.

The aim of this paper is to illuminate the potential of AI and ML as catalysts for a re-imagined, enhanced, and more inclusive science education landscape. The scope of this paper is to provide a thorough analysis of the multifaceted aspects surrounding the use of AI and ML in science education. It seeks to provide educators, policymakers, researchers, and stakeholders with a holistic view of the subject matter by addressing the key areas.

Historical antecedents of AI and ML.

Holmes and Tuomi (2022) in a review of the historical development of AI amid claims and counter claims of its genesis, traced its precursors to Polya's (1945) *how to solve it* in which different heuristics for problem solving were presented with the aim of decreasing or shortening the pathway from a problem to its known solution. Further works by E. L Thorndike who in his *law of effect*, Nowell and Simon's *thinking machine*, Pressey's first mechanized multiple choice machine and B. F Skinner's behaviourism were earlier attempts at automating learning via machines. Further development of these earlier ideas resulted in the first Self-adaptive key board instructor (SAKI) a teaching machine developed by Pask and the SCHOLAR put forward by Carbonell in 1970 (see Holmes & Tuomi, 2022 for details). These initial ideas provided the basis for improving learning and teaching as well as provide structured aids to how individuals can solve problems with relative ease.

It is thus of importance to note that due to this many decades of development of the ideas in this field of research, AI and ML are often conceptualized as a field of research in learning rather than a specific machine or tool.

2. Concept of Artificial intelligence (AI) and Machine learning (ML)

Artificial intelligence (AI) refers to the simulation of human intelligence processes by machines, especially computer systems. Morandín-Ahuerma (2022) sees Artificial intelligence as the ability of a machine or computer system to simulate and perform tasks that require human intelligence, such as logical reasoning (using rules to reach approximate or definite conclusions), learning (the acquisition of information and rules for using the information), and problem solving, reasoning, perception and language understanding. In the same light, Arunagiri & Sumana (2023), Dave & Kavathiya (2023) and Galbusera et al., (2019) have variously noted that AI consists of a variety of techniques and approaches, including machine learning (where machines learn from data), natural language processing (enabling computers to understand and generate human language), computer vision (enabling computers to interpret visual information), and robotics (creating machines capable of performing tasks in the physical world). AI aims to create systems that can perform tasks that would typically require human intelligence. UNICEF, (2021) in what looks like a holistic consideration conceptualized AI as “machine-based systems that can, given a set of human-defined objectives, make predictions, recommendations, or decisions that influence real or virtual environments” (p. 16). this definition captures the essence of AI in education and science education in particular.

Machine learning (ML) as explained by Dhanalaxmi (2020) as a subset of artificial intelligence (AI) with capacity to develop algorithms and statistical models with which computers systems can execute tasks without definitive instructions but only relying on patterns and inference. This view about the meaning of ML is also expressed by Kawahara (2020) and Shameer et al. (2018). In other words, machine learning allows computers to learn from available data and improve over time without being programmed for every task. Ray (2019) listed several types of machine learning approaches, including:

- Supervised learning which refers to training the algorithm using labeled data pairs where each input has an output label attached to it to help the algorithm learn how to associate inputs with outputs and then enable it to predict or make decisions based on learned associations.
- Unsupervised learning which entails training algorithms with data to uncover hidden patterns or structures in the information provided. These include clustering and dimensional reduction.
- Reinforcement learning which is a form of machine learning in which an agent learns to make decisions by engaging with its surroundings and receiving feedback through rewards or penalties depending on its actions, with the aim of increasing reward over time.

3. Science Education domain

Science education is an academic area that studies of how people learn and understand scientific concepts, principles, and practices. It involves both the theory and practice of designing science curriculum and materials, developing science curriculum contents, pedagogues for science curriculum implementation, strategies and issues in science learning as well as developing assessment strategies for science learning outcomes. The discipline provides practitioners knowledge and competencies to

- Understand the core concepts and principles across scientific disciplines such as biology, chemistry, physics, and allied areas thereby harnessing their areas of relationship to build strategies for deeper understanding of their interconnections. This knowledge forms the foundation for effective teaching, communication and collaborations in science education research.
- develop and nurture pedagogical content knowledge, which involves understanding how to teach specific science concepts effectively and addressing common misconceptions often associated with science learning, and methods for engaging students in scientific inquiry.
- draw on principles of educational psychology such as learning theories, theories of motivation and theories of cognitive development to understand how students learn science and to develop instructional approaches that accommodate diverse learning styles and cognitive abilities.
- design and develop science curricula that inclusive, selecting appropriate content for diverse groups, sequencing such concepts, and integrating cross-cutting themes such as scientific inquiry, critical thinking, and science, technology, engineering, and Mathematics into everyday science learning.
- develop and implement assessment strategies and techniques for evaluating students' understanding of scientific concepts and their ability to reason scientifically while as well as using assessment data to make

instructional decisions that improve science teaching practice.

- engage in continuous professional development such as workshops, conferences,and collaborative research projects to keep practitioners abreast of advances in both science content, pedagogy and educational research trends.

4. AI and ML in Science Education

The pervasive incursion of AI and ML has multifarious impact in the field of science education as in other areas of learning. Notable among them are:

1. In the domain of science education, AI and ML have transformed the way students learn and interact with scientific concepts, offering personalized learning and providing for individual students according to learning needs, progress, and preferences (Oancea et al., 2023). This is achieved by using AI and ML algorithms to analyze large amounts of educational data on students' performance, engagement, and learning history (Patero, 2023; Struyf et al., 2019). Such huge databases are leveraged on by educational platforms to create adaptive learning pathways that adjust in real-time based on each student's progress and comprehension level.
Related to the above is the ability to providing tailored content delivery pathways to suit every student's unique learning style and pace which oftentimes is of advantage to science education content implementation (Tenon, & Epler, 2020; Asaad, 2017). AI and ML technologies assists science educators creating and delivering contents in a manner that resonates with individual students. AI systems can craft content delivery methods that align with how each student learns best from available students' data in such a way that visual learners receive contents enhanced with visual aids and interactive simulations, while contents for auditory learners is fortifies with audio explanations thus fostering understanding and engagement with learning materials. It also takes into account students' interests and real-world applications of scientific knowledge, creating a more meaningful learning experience, a sense of empowerment and enthusiasm and enhanced learning outcome (Aditi, 2022).

2. The integration of Artificial Intelligence (AI) and Machine Learning (ML) technologies into field of science education has ushered in a new era of experiential learning through real-world simulation previously confined to physical laboratories and field studies. Also, AI and ML-powered virtual laboratories now offers students access to experiments that might be too expensive, logistically challenging, or even hazardous in real-life physical laboratory settings with minimal safety concerns. With AI and ML technologies, students of chemistry, biology, physics and engineering can now manipulate variables, observe reactions, and collect data just as they would in physical laboratories and workshops thus enhancing their understanding of scientific principles and practical skills (Abill et al., 2024). The advent of AI-powered animations, 3D visualizations, and interactive models now enables students to explore concepts that are otherwise difficult to grasp. Concepts like molecular interactions, planetary orbits, and cellular processes can now be visualized making them tangible, comprehensible thus fostering curiosity, engagement and deeper connection to the subject matter (Dede et al., 1997).

3. Science deals with and generates huge data from experiments and research. AI and ML have become useful in managing, processing and analyzing such large data with relative ease and accuracy (Linn, 2003) using their pattern recognition and predictive modeling features. These features enable AI go through huge datasets and identify relationships, correlations, trends, and outliers that ordinary analogue human analysis cannot achieve. This analytical prowess enables science educators and students to undertake deep exploration of scientific phenomena, gain exposure to real-world data analysis scenarios, as well as equip them with skills that extend beyond the classroom.

Apart from analyzing data, AI and ML technologies enable more visually engaging and informative representations of complex datasets in form of graphs, charts, heatmaps, and interactive models that enable science students, teacher and researchers develop intuitive ways to comprehend intricate data. Visual representations are powerful tools for communicating abstract concepts, making it easier for students to grasp complex scientific ideas (Partarakis & Zabulis (2024), identify changing trends such as in climate data, decipher progression in studies of biological processes, or the interactions within complex chemical systems. Translating data into visual forms, help science educators to bridge the gap between theory and practice, empowering students to interact with data and draw meaningful conclusions. AI-driven data analysis and visualization are also important in nurturing skills that are valuable in the modern technology and science education workplace environments (Hohman, et al., 2019) offering a paradigm shift in how data is harnessed for educational purposes. As AI advance, so too does its potential to transform the learning journey of science educators into a dynamic, data-driven exploration of the natural world.

4. The role of Artificial Intelligence (AI) and Machine Learning (ML) technologies in generating instant feedback and assessment hold great consequences for effective evaluation of science learning outcomes. Delays in feedback from assignment and tests are often overcome when AI and ML technologies are applied into performance studies thus leading to more effective assessment capabilities González-Calatayud, et al., 2021). Educational platforms utilizing AI are able to evaluate student responses in real time and provide quick feedback on science quizzes, assignments, and interactive exercises (Yu, 2024; Kamalov et al., 2023; Chen et al, 2020; Abang et al., 2023; Owan et al., 2023) thus creating a rapid response feedback loop enabling students to gauge their understandings of scientific concepts. In addition, AI can analyze patterns in student performance over time, identifying areas of strength and weakness, providing Science educators needed information on how best to tailor instruction based on individual needs, offering targeted interventions to support struggling students and challenges to those who excel (Bagunaid et al., 2022).

5. Students can analyse their progress, engage in self-assessment of their learning journey, and highlight areas that need additional research with the use of AI-supported platforms (Bagunaid et al., 2022; Owan et al., 2023). Self-assessment findings frequently help and excite students because they foster a growth mindset—a mindset that views barriers as chances for improvement rather than as a means of achieving one’s goals—and boost self-awareness. Moreover, based on a student’s performance, AI and ML technologies can provide extra materials or exercises. The platform can provide extra resources or practice tasks that are customized for each learner in case they are having trouble with a particular idea. With the help of this individualized coaching, students can fix their shortcomings and and reinforce their understanding of scientific principles

5. Issues and Considerations of AI and ML use in science Teaching

Despite the many advantages of AI and ML in science education, Zhai et al. (2021) found certain difficulties with their application in science teaching and learning after reviewing the literature over a ten-year period. Common knowledge, best practices, students' knowledge, and attitudes towards AI and ML opportunities and problems are only a few of the difficulties that Kuleto et al. (2021) mentioned in their list of difficulties integrating AI and ML in higher education.

Moral Issues. There are several ethical issues that come up when the use of AI and ML technologies in science teaching becomes more widespread. Although these technologies have revolutionary potential, they also bring up difficult problems that require serious consideration and deliberate responses (Zhai et al., 2021; Rizvi et al., 2021)

5.1 Protecting student information and maintaining data privacy.

For AI and ML to work properly, data is required, and this data frequently consists of learning patterns, personal information, and student performance statistics. Security and privacy issues are raised by the gathering and use of such data. Comprehensive safety protocols must be in place to protect student data from misuse, illicit access, and breaches at educational institutions and technology providers. Safeguarding the integrity of the educational experience and preserving student trust requires strict adherence to data privacy standards and transparency in data gathering processes. A difficult balance must be struck between the requirement for data-driven insights and the necessity to safeguard students' sensitive information. To lessen the dangers related to data privacy, comprehensive privacy rules, open data handling procedures, and unambiguous permission procedures are crucial.

AI algorithms may contain bias and may reinforce preexisting inequities. When AI algorithms learn from past data, biases in that data may unintentionally be encoded. Biased algorithms have the potential to maintain differences in learning results in the context of science education, especially if they unintentionally benefit some groups while systematically harming others. This keeps marginalized communities under-represented in STEM disciplines and maintains already-existing educational disparities. It takes careful observation, ongoing improvement, and varied representation in the development process to address bias in AI algorithms. Together, educators and technologists must recognize and address prejudices to guarantee that AI-powered learning resources are inclusive and egalitarian. This makes it possible for the education community to actively battle bias, promote a culture of responsibility and openness, and create a more

Technological Barriers: In order to ensure fair and efficient implementation, a number of technological issues posed by the integration of AI and ML technologies in science education must be addressed

(Hwang et al., 2020). Among these technological obstacles are

Fairness and Availability of AI-Powered Resources. AI and ML technologies have great potential for science education, but only if they are available to all students. Regrettably, not all areas, socioeconomic backgrounds, and educational institutions have equal access to technology, particularly in developing nations. Inequalities in education could be made worse if certain students are unable to access resources driven by artificial intelligence. Initiatives aimed at closing the digital divide must be given top priority by educators and policymakers. This could entail giving cloud-based solutions that are more accessible even with restricted hardware, guaranteeing internet connectivity in under-served areas, or subsidizing technology. Ensuring that learning experiences enhanced by AI and ML are inclusive and accessible to all is crucial.

To effectively utilize and realize the benefits of AI and ML in science education, regular and continual energy availability is necessary for powering learning tools and equipment. The high expense and unreliability of epileptic energy supplies may prevent the many advantages of AI technology from being fully realized.

Training Teachers for the Successful Integration of AI Tools. In order to successfully incorporate AI and ML into scientific education, teachers must be equipped with the skills and knowledge needed to make the most of these technologies. It is difficult to give scientific instructors thorough training since it takes money, time, and a dedication to continuous professional growth. In addition to teaching teachers how to use AI technologies technically, teacher preparation programs should also teach them how to seamlessly integrate these tools into science curricula. Teachers need to know how to analyse AI-generated insights, match learning objectives with AI-powered resources, and make sure that technology complements human intervention in science teaching rather than takes its place.

Diminished Human Communication. Although there are many advantages to integrating AI and ML, there is worry that this could lessen the importance of human engagement in the learning process. Interactions among science students, instructors, peers, and mentors support the development of social skills, critical thinking, and holistic growth. Through these exchanges, students are able to clarify issues, pose queries, participate in discussions, and get one-on-one help that goes beyond automated answers. If AI is used excessively for assessment and content delivery, these important facets of education may unintentionally suffer. Therefore, in order to establish an ecosystem where AI augments rather than replaces the crucial human parts of education, scientific educators must find a balance between AI-driven technologies and the demands of their students for human connection. While science educators concentrate on encouraging discussions, directing inquiry, and mentoring students, AI can act as a facilitator, offering customized content and real-time feedback by carefully designing learning experiences that weave AI and ML technologies into the fabric of collaborative and communicative environments. resulting in the development of an educational environment that maximizes technical breakthroughs while preserving the richness of human connection.

Influence On The Development Of Communication and Teamwork Skills. Proper integration of AI and ML technologies into science education has the potential to change not just how students study, but also how they interact and communicate with one another. While there are many advantages of AI, there are also worries about how it may affect communication and collaboration abilities, which are critical for both professional and personal development in science domains (Moemeke, 2023). Students participate in group discussions, peer-to-peer exchanges, and cooperative projects in traditional learning environments. These encounters promote the growth of empathy, interpersonal skills, and the capacity to collaborate well in a variety of teams. However, there are concerns that if AI-powered personalized learning gains traction, students will engage with technology more than their classmates. The fact that scientific knowledge is negotiated by a professional community of scientists, educators, and researchers through cooperation, communication, and the refining of viewpoints, exacerbates this worry. Science educators and AI/ML-powered tools need to work together to purposefully include cooperative activities into science-based learning experiences. Students can practise effective communication and the art of teamwork through group projects, debates, and interactive problem-solving exercises. A careful incorporation of AI-powered resources into these kinds of cooperative environments, will enable science educators create a balance between individualized instruction and the development of social skills.

Over-reliance on AI. While AI and ML technologies hold the promise of enhancing teaching and learning, there lie a notable concern regarding the potential over-reliance on these tools. As students become accustomed to instant answers and guided learning pathways, the risk that their critical thinking and problem-solving skills might diminish increases as well (Gligorea et al., 2023; Kuleto et al., 2021). Relying solely on AI to provide solutions can hinder students from grappling with complex concepts independently and from developing the analytical skills needed for lifelong learning. In mitigating this challenge, science educators and practitioners must actively encourage a blended approach that combines AI-driven resources with traditional problem-solving methodologies. Encouraging students to explore solutions independently, engage in open-ended inquiries, and devise strategies to solve unfamiliar problems is essential. AI can serve as a valuable resource, offering insights and guidance, but educators must create learning experiences that foster curiosity, experimentation, and resilience in the face of challenges. It should be noted that one of the factors that enhance enquiry is when a scientist arrives at some questions that are unanswered by a known formula, this triggers further questions and actions and oftentimes result in breakthroughs.

Furthermore, educators need to foster a culture that celebrates curiosity, intellectual exploration, and the value of not knowing all the answers. Promoting growth mindset and encouraging students to push the boundaries of their knowledge, ensures that AI's role remains complementary rather than inhibitory to the development of critical thinking and problem-solving skills and scientific research development.

The integration of AI and ML technologies in science education necessitates a mindful approach to the preservation of collaborative and communication skills, as well as the cultivation of critical thinking and problem-solving abilities. Designing learning experiences that strike a harmonious balance between AI-driven assistance and the fostering of core competencies, enhance the harness of the benefits of technology while nurturing the holistic growth of students.

AI and ML-powered educational platforms

There are innovative AI and ML-technology powered educational platforms that have transformed the ways students learn and educators teach science -based disciplines. Some of them are here highlighted.

2. Smart Sparrow (https://www.smartsparrow.com/ is an AI-powered platform that offers adaptive e-Learning solutions. It allows educators to design interactive, data-rich lessons that for real-time to students' responses. The platform provides instant feedback and guidance, fostering engagement and improving learning outcomes. Smart Sparrow's case studies have shown improved retention rates and deeper conceptual understanding across various subjects. Hu, (2021) reported notable improvements in learning outcomes when Smart Sparrow was implemented in university science courses. Students who used the platform showed higher levels of mastery in course content compared to those in traditional lecture-based classes. The adaptive nature of Smart Sparrow allowed students to focus on areas where they needed more support, leading to improved retention and comprehension.

3. DreamBox Learning, an AI-driven math program designed to adapt to each student's learning pace and style. Its algorithms continuously analyze student interactions to offer personalized lessons that cater to their strengths and weaknesses. The platform encourages exploration and problem-solving, aligning with students' individual abilities and ensuring a deeper understanding of mathematical concepts. Dabingaya (2022) and Chen (2019) reported that students using DreamBox consistently outperformed their peers on standardized math assessments. The program's adaptive nature allowed students to progress at their own pace, resulting in deeper conceptual understanding and higher achievement scores.

4. Coursera, a leading online learning platform that employs AI to enhance student engagement and retention analyzes data on course interactions, completion rates, and assessment performance, as well as offers recommendations to students on how to succeed in their chosen courses. The inherent AI-powered peer reviews and instant feedback mechanisms also contribute to a more interactive and effective learning experience. Ayo (2023) and Salam et al., (2023) reported that Coursera enhanced student engagement and improved learning outcomes through data-driven recommendations and thatstudents who followed Coursera's personalized study plans generated through AI analysis of their interactions, demonstrated higher completion rates and more consistent engagement with course content.

5. Labster, a platform that offers virtual laboratory simulations that enable students to conduct experiments in a risk-free digital environment. The platform employs AI to provide instant feedback, guide students through experiments, and simulate complex scientific phenomena (Acero, 2023). Labster's immersive simulations help bridge the gap between theory and practice, enhancing students' practical understanding of scientific concepts though Dyrberg et al., (2017) earlier reported no difference in student motivation.

6. Gradescope is an AI-assisted grading platform used in secondary and higher education institutions. It streamlines the grading process for assignments and exams, utilizing ML to recognize and categorize different answer formats. Educators can provide feedback more efficiently, and students receive detailed feedback faster. Gradescope enhances the grading experience for both educators and learners, allowing more time for instructional interactions.

Sana Labs is an AI-powered platform that transforms higher education by offering personalized learning experiences. It analyzes individual learning patterns and preferences to curate course content that matches students' needs. Sana Labs' case studies demonstrate improved learning outcomes, increased engagement, and higher completion rates for university courses. The platform empowers students to take ownership of their learning journey, enhancing their understanding of complex subjects.

Carnegie Learning Carnegie Learning offers AI-driven math curricula spanning from elementary to higher education. The platform personalizes lessons and assessments based on each student's strengths and areas requiring improvement. It employs AI-generated hints and solutions to guide students through problem-solving processes. Carnegie Learning's data-driven approach improves students' math proficiency and instills problem-solving skills across educational levels.

6. Recommendations for Effective AI and ML Integration into Science Education Delivery

Training and Professional Development

To ensure the successful integration of Artificial Intelligence (AI) and Machine Learning (ML) technologies in science education, a comprehensive approach to training and professional development is essential. Educators and stakeholders need to be equipped with the necessary knowledge and skills to harness the full potential of these technologies. This can be achieved by establishing training programs that empower science educators with the technical expertise needed to effectively integrate AI and ML technologies into their teaching practices. Workshops, webinars, and online courses can offer insights into the capabilities and limitations of AI tools, allowing educators to make informed decisions about their use in the classroom.

complementing technical training with pedagogical guidance on how to design curriculum and learning experiences that leverage AI-driven tools. Science educators should be trained in creating engaging content, designing activities that promote critical thinking, and effectively blending AI assistance with human guidance to enhance learning outcomes.

collaborating with EdTech experts who specialize in AI and ML integration. These experts can offer insights into best practices, share case studies, and provide guidance on selecting appropriate tools that align with educational goals.

fostering peer learning communities where educators can share experiences, insights, and challenges related to AI integration. Collaborative spaces provide opportunities to exchange ideas, troubleshoot issues, and collectively develop strategies for effective implementation.

providing incentives for professional growth to science educators to engage in continuous professional development related to AI and ML technologies and reward educators who actively seek to enhance their skills in integrating technology, thereby creating a culture of lifelong learning and innovation.

offering institutional support for training initiatives such as allocating resources for training programs, providing access to technology infrastructure, and integrating AI-focused training into broader professional development frameworks.

7. involving students in the process of integrating AI and ML technologies can provide insights into how these tools resonate with their learning styles and preferences thus provide feedback that can guide refinements and improvements in the implementation process.

8. Providing Teachers with the Necessary Skills to Effectively Use AI and ML Tools. As the integration of Artificial Intelligence (AI) and Machine Learning (ML) technologies in science education gains prominence, it is imperative to empower educators with the skills to navigate these tools adeptly. This involves a comprehensive approach to training that enables teachers to harness the potential of AI and ML for enriched learning experiences through targeted workshops and courses designed specifically and tailored to educators, focusing on the practical application of AI and ML tools in science education; hands-on experience that provide educators with hands-on experience in using AI and ML tools; peer coaching that encourage science educators who have successfully integrated AI and ML tools to serve as peer coaches. These coaches can guide their colleagues through the process, offering insights, troubleshooting assistance, and sharing best practices.

9. Continuous Learning to Keep Up with Evolving Technology. The field of AI and ML is rapidly evolving, and educators must embrace a mindset of continuous learning to stay abreast of advancements. AI-powered tools and techniques are constantly improving, and STEM educators need to adapt to fully leverage their potential.

10. Foster a culture of continuous learning within educational institutions. Encourage educators to engage in regular upskilling and professional development opportunities related to AI and ML.

11. Access to Resources: Provide educators with access to a repository of resources, including articles, webinars, online courses, and research papers, to keep them informed about the latest developments in AI and ML technologies.

12. establish channels for educators to receive updates on AI and ML trends, breakthroughs, and emerging tools. Regular communication ensures that educators are aware of new possibilities and can integrate them into their teaching practices.

13. collaborating with AI and tech industry professionals to facilitate technology updates and insights directly from experts. Industry partnerships can offer educators practical insights into the applications and implications of cutting-edge AI technologies.

Ensuring equity in access to AI and ML infrastructure

As AI and Machine Learning (ML) technologies become integral to science education, it is crucial to ensure equitable access to these resources, irrespective of students' backgrounds or circumstances. Prioritizing inclusiveness in educational institutions can minimize disparities in access and create a level playing field for all learners. This can be achieved by

- investing in technology infrastructure to bridge the digital divide by individuals, interest groups and IT professionals. This ensures that students from all socioeconomic backgrounds have access to devices and reliable internet connections required for utilizing AI-powered resources.
- adopting cloud-based platforms for AI integration. Cloud solutions minimize hardware requirements, making AI resources more accessible on a wider range of devices, including low-end devices that students might possess.
- developing offline or hybrid models that allow science students to access AI resources even in low-connectivity areas. This ensures that learners in remote or under-served locations can also benefit from AI-driven educational tools.

Mitigating Potential Bias and Discrimination in AI Algorithms

AI algorithms can inadvertently perpetuate biases present in historical data, potentially leading to discriminatory outcomes. To ensure equity in AI integration, educational institutions must

- use diverse and representative datasets during the development of AI algorithms to ensure that the data used for training is inclusive and encompasses various demographic groups, thereby minimizing the risk of reinforcing biases.
- undertake periodic audit of AI algorithms to identify and rectify biases that might emerge over time and implement mechanisms to detect and correct instances where algorithms produce unequal or biased outcomes.
- foster transparency in AI implementation by providing information on how algorithms make decisions so as to offer explanation on the logic behind AI-generated recommendations and ensure students and educators understand the basis for the insights provided.
- put in place ethics committees or guidelines for AI integration in science education. These provide oversight and review the ethical implications of AI-powered tools, ensuring that they align with educational values and principles.
- integrate educational modules that address algorithmic bias into curricula and educate students about the ethical concerns associated with AI and empower them to critically evaluate AI-generated information.

Balancing AI and Human Interaction

1. Guidelines for Maintaining a Healthy Balance Between AI Assistance and Human Guidance

The successful integration of Artificial Intelligence (AI) and Machine Learning (ML) technologies in science education hinges on finding the right balance between technology-driven assistance and human interaction. This equilibrium ensures that AI enhances, rather than replaces, the essential role of educators and human connections. Achieving this requires

- developing guidelines that emphasize the alignment of AI tools with educational goals. AI should complement instructional objectives rather than dominate them. Encourage educators to integrate AI in ways that enhance learning experiences and foster meaningful engagement.
- establish thresholds for AI involvement in different aspects of education. Determine when AI-generated insights should be supplemented by human input, such as facilitating discussions, providing context, and addressing students' emotional needs.
- promote a mix of individualized learning through AI and collaborative learning through human interactions. This encourages students to engage in group discussions, peer evaluations, and collaborative projects that foster teamwork and communication skills.

2. Fostering Critical Thinking and Problem-Solving Alongside AI-Driven Learning

While AI can offer valuable insights, it is of essence to cultivate students' critical thinking and problem-solving skills alongside the use of AI tools. Nurturing these competencies ensures that students are well-equipped to navigate complex challenges independently.

- design assignments and projects that require students to think critically and solve problems without direct AI assistance. Encourage students to analyze, synthesize, and evaluate information from multiple sources to arrive at well-informed conclusions.
- encourage students to question and critically evaluate AI-generated insights. Students should be taught how to assess the reliability of AI recommendations, identify potential biases, and verify information through independent research.
- integrate real-world scenarios and challenges that demand creative problem-solving by encouraging science students to apply their knowledge to practical

situations, considering diverse perspectives and potential solutions.

• engage students to question issues (Socratic dialogues) that stimulate critical thinking by encouraging them to explore complex questions, articulate their reasoning, and engage in open discussions that foster intellectual growth.

Increasing Human Interaction

As AI and Machine Learning (ML) technologies revolutionize science education, it is vital to strike a delicate balance between leveraging technological advancements and preserving the essential role of face-to-face interactions. Human connections play a crucial role in holistic learning, and science educators and their students should ensure that technology enhances, rather than supplants, these interactions.

• designing, implementing and engaging in structured classroom discussions that encourage students to engage with peers and educators on meaningful topics. These interactions can foster critical thinking, collaboration, and a sense of community involvement.

• Implement hybrid learning models that combine AI-driven individualized learning with regular in-person interactions. This approach allows students to benefit from technology while still participating in group discussions, debates, and hands-on activities.

• create blended learning environments that integrate online and offline interactions. This is to encourage students to use AI for content consumption and practice, while reserving in-person interactions for deep discussions, collaborative projects, and experiential learning.

Impact of AI and ML on Collaborative and Communication Skills

The integration of AI and ML technologies brings unprecedented opportunities for learning, but science educators must be attentive to their potential impact on collaborative and communication skills. These skills remain crucial for success in various aspects of life and science learning, and AI should be harnessed to enhance, rather than overshadow, their development.

• design assignments that require teamwork, where students must collaborate, brainstorm, and collectively solve problems. This approach holds the potential to reinforce collaboration and cultivate communication skills, showing students the value of working together.

• encourage interdisciplinary projects that demand collaboration between students with different backgrounds. These projects often encourage students to communicate effectively across diverse perspectives and contribute their expertise to achieving shared goal.

Future of AI and ML in science Education development

The integration of Artificial Intelligence (AI) and Machine Learning (ML) technologies in science education holds the promise of transforming and reshaping the way students learn and educators teach science. Looking ahead,

1. AI-driven tools will become increasingly proficient at tailoring learning experiences to individual students' needs, preferences, and learning paces. Advances in AI algorithms are likely to generate hyper-personalized learning pathways that adjust content and challenges in real time to optimize engagement and comprehension of science concepts.
2. AI-powered virtual laboratories will provide immersive and realistic hands-on experiences for students, allowing them to conduct experiments, explore scientific phenomena, and analyze data in a risk-free digital environment thus bridging the gap between theoretical knowledge and practical application as well as enable students grasp complex concepts with greater ease.
3. AR and VR technologies, combined with AI, will enable students to interact with three-dimensional models of molecules, ecosystems, and other scientific concepts. These technologies will offer students a deeper understanding by allowing them to manipulate and explore complex structures in a highly engaging and interactive manner.
4. AI will continue to provide science educators with actionable insights by analyzing student performance data. This enable science educators a more precise way to identify areas of struggle, strengths, and learning trends, allowing them to personalize instruction, provide timely interventions, and adapt their teaching strategies to meet students' diverse needs.
5. AI tools will be incorporated into curricula to teach ethical considerations related to AI use, algorithmic bias, and data privacy thus emphasizing critical thinking by prompting students to analyze AI-generated content, assess its reliability, and develop a nuanced understanding of the role of technology in society.

7. AI and ML technologies will extend their reach beyond formal education, acting as lifelong learning companions. Individuals of all ages will access personalized learning resources, skill-building modules, and AI-assisted learning experiences to continuously develop their knowledge and expertise.

7. Summary and Conclusions

The integration of Artificial Intelligence (AI) and Machine Learning (ML) technologies in science education represents a transformative leap forward in the way students learn and educators teach. Throughout this position paper, we have explored the multifaceted landscape of the roles of AI and ML in science education, delving into its benefits, challenges, and recommendations for effective integration.

We began by examining the potential benefits of AI and ML in science education, highlighting how these technologies enhance personalization by adapting learning pathways and content delivery to individual students. We explored how real-world simulations and data analysis visualizations offer experiential and comprehensive learning experiences, expanding students' practical understanding of complex scientific concepts. The paper then delved into the instant feedback and assessment capabilities of AI, emphasizing the value of immediate assessment for student performance and the opportunities for self-improvement that AI-driven tools provide. Additionally, we addressed the ethical concerns surrounding AI and ML, focusing on the need to safeguard data privacy, mitigate algorithmic bias, and ensure equitable access to resources. Issues such as technological barriers and potential loss of human interaction were discussed, emphasizing the importance of equitable access to AI-powered resources and providing training for educators to effectively integrate these tools. Furthermore, we addressed the potential impact on collaborative and communication skills, highlighting the significance of nurturing these competencies alongside AI-driven learning in science students. We forecast a future science education landscape rich with hyper-personalized learning, intelligent virtual laboratories, AR/VR enhancements, and data-driven insights for both science educators and their students. The paper emphasized the potential for AI to become a lifelong learning partner, supporting individuals of all ages in their pursuit of knowledge and skills.

In conclusion, the integration of AI and ML technologies in science education holds the potential to revolutionize science learning experiences in the near future. When the challenges of nurturing human interaction, and prioritizing equitable access are addressed, we can harness the benefits of technology while upholding the core values of science education and scientific research. This transformative journey demands a harmonious blend of AI-powered tools and the expertise of science educators in creating an educational landscape that prepares students for a future where technology and humanity coexist in harmonious synergy. We also conclude for this to happen, there is need for equitable distribution and availability of AI and ML resources across sections, segments, classes of people and economies to ensure equal access and opportunities for all.

References

Abang, K., Idika, D., Etta, E., & Bassey, B. (2023). Exploring the potential of artificial intelligence tools in educational measurement and assessment. *Eurasia Journal of Mathematics, Science and Technology Education*. https://doi.org/10.29333/ejmste/13428.

Abill, R., Kaledio, P., Louis, F (2024)The Impact of Artificial Intelligence on Students' Learning Experience. Wiley Interdisciplinary Reviews: Computational Statistics DOI: 10.2139/ssrn.4716747

Aditi, B (2022). Personalized education and Artificial Intelligence in the United States, China, and India: A systematic review using a Human-In-The-Loop model. Computers and Education: Artificial Intelligence 3. https://doi.org/10.1016/j.caeai.2022.100068

Acero, L. (2023). Challenges And Opportunities In The Study Of Cell Using Virtual Online Laboratory. *International Journal on Bioinformatics & Biosciences*. https://doi.org/10.5121/ijbb.2023.13101.

Aggarwal, D., Sharma, D., & Saxena, A. (2023). Exploring the Role of Artificial Intelligence for Augmentation of Adaptable Sustainable Education. *Asian Journal of Advanced Research and Reports*. https://doi.org/10.9734/ajarr/2023/v17i11563.

Anshari, M., Almunawar, M., Shahrill, M., Wicaksono, D., & Huda, M. (2017). Smartphones usage in the classrooms: Learning aid or interference?. Education and Information Technologies, 22, 3063-3079. https://doi.org/10.1007/s10639-017-9572-7.

Arunagiri, G and Sumana S. (2023)"Modern Artificial Intelligence-An Overview." *Journal of Artificial Intelligence and Capsule Networks* 5(3)268-279 https://doi.org/10.36548/jaicn.2023.3.004.

Asaad, D. (2017). Personalized Adaptive Learning Impact on the Student Experience: Stakeholders' Perspectives (Doctoral dissertation, National American University).

Asad, M., Naz, A., Churi, P., & Tahanzadeh, M. (2021). Virtual Reality as Pedagogical Tool to Enhance Experiential Learning: A Systematic Literature Review. Education Research International. https://doi.org/10.1155/2021/7061623.

Ayo, E. (2023). Blending Coursera in CEU Courses: A Study on the Quality and Educational Impact. *GEO Academic Journal*. https://doi.org/10.56738/issn29603986.geo2023.4.43.

Bagunaid, W., Chilamkurti, N., & Veeraraghavan, P. (2022). AISAR: Artificial Intelligence-Based

Student Assessment and Recommendation System for E-Learning in Big Data. Sustainability. https://doi.org/10.3390/su141710551.

Bilow, S. (2020). Introduction: AL and Machine Learning. *Smpte Motion Imaging Journal*, 129, 14-15. https://doi.org/10.5594/JMI.2020.2964182.

Bondac, G., & Hrestic, L. (2023). Digitization of the Educational Environment-an Inevitable Change. *Valahian Journal of Economic Studies*, 14, 59 - 66. https://doi.org/10.2478/vjes-2023-0007.

Castelli, F., & Sarvary, M. (2021). Why students do not turn on their video cameras during online classes and an equitable and inclusive plan to encourage them to do so. Ecology and Evolution, 11, 3565- 3576. https://doi.org/10.1002/ece3.7123.

Chen, L., Chen, P., & Lin, Z. (2020). Artificial Intelligence in Education: A Review. IEEE Access, 8, 75264-75278. https://doi.org/10.1109/ACCESS.2020.2988510.

Chen, Y. (2019). Effect of Mobile Augmented Reality on Learning Performance, Motivation, and Math Anxiety in a Math Course. *Journal of Educational Computing Research*, 57, 1695 - 1722. https://doi.org/10.1177/0735633119854036.

Cheung, S.K.S., Kwok, L.F., Phusavat, K. et al. (2021) Shaping the future learning environments with smart elements: challenges and opportunities. Int J Educ Technol High Educ 18, 16. https://doi.org/10.1186/s41239-021-00254-1

Condruzbacescu, M. (2020). Promoting Open Education and Free Educational Resources. eLearning and Software for Education. https://doi.org/10.12753/2066-026x-20-039.

Crawford, R. (2017). Rethinking teaching and learning pedagogy for education in the twenty-first century: blended learning in music education. Music Education Research, 19, 195 - 213. https://doi.org/10.1080/14613808.2016.1202223.

Dabingaya, M. (2022). Analyzing the Effectiveness of AI-Powered Adaptive Learning Platforms in Mathematics Education. *Interdisciplinary Journal Papier Human Review*. https://doi.org/10.47667/ijphr.v3i1.226.

Dave, N., & Kavathiya, H. (2023). AI in Robotics: Advancements, Applications and Challenges. *Journal of Information Technology and Digital World* 5(2)193-209 https://doi.org/10.36548/jitdw.2023.2.009.

Dede, C., Salzman, M., Loftin, R. B., & Ash, K. (1997). Using virtual reality technology to convey abstract scientific concepts. Learning the Sciences of the 21st Century: Research, Design, and Implementing Advanced Technology Learning Environments. Lawrence Erlbaum: Hillsdale, NJ.

Dhanalaxmi, B. (2020). Machine Learning and its Emergence in the Modern World and its Contribution to Artificial Intelligence. 2020 International Conference for Emerging Technology (INCET), 1-4. https://doi.org/10.1109/incet49848.2020.9154058.

Dyrberg, N., Treusch, A., & Wiegand, C. (2017). Virtual laboratories in science education: Students' motivation and experiences in two tertiary biology courses. *Journal of Biological Education*, 51, 358 - 374. https://doi.org/10.1080/00219266.2016.1257498.

Faridi, M., & Ebad, R. (2018). Transformation of higher education sector through massive open online courses in Saudi Arabia. Problems and Perspectives in Management. https://doi.org/10.21511/PPM.16(2).2018.20

Franks, M. (2020). Protecting Privacy and Security in Online Instruction: A Guide for Students and Faculty. https://doi.org/10.2139/ssrn.3668553.

Galbusera, F., Casaroli, G., & Bassani, T. (2019). Artificial intelligence and machine learning in spine research. JOR Spine, 2. https://doi.org/10.1002/jsp2.1044.

Gligorea, I., Cioca, M., Oancea, R., Gorski, A., Gorski, H., & Tudorache, P. (2023). Adaptive Learning Using Artificial Intelligence in e-Learning: A Literature Review. Education Sciences. https://doi.org/10.3390/educsci13121216.

González-Calatayud, V., Prendes-Espinosa, P., & Roig-Vila, R. (2021). Artificial Intelligence for Student Assessment: A Systematic Review. Applied Sciences. https://doi.org/10.3390/APP11125467.

Groff, J. (2013). Technology-rich innovative learning environments. OCED CERI Innovative Learning Environment project, 2013, 1-30.

Guaña-Moya, J., Arteaga-Alcívar, Y., Chiluisa-Chiluisa, M., & Begnini-Domínguez, L. (2022). Evolution of Information and Communication Technologies in Education. 2022 Third International Conference on Information Systems and Software Technologies (ICI2ST), 138-144. https://doi.org/10.1109/ICI2ST57350.2022.00027.

Haidir, N. K. H. (2023). Bridging the Gap: How Technology Integration is Transforming the Classroom Experience. *International Journal of English Language and Pedagogy*, 1(2), 100–109. https://doi.org/10.33830/ijelp.v1i2.6502

Haleem, A., Javaid, M., Qadri, M. A., & Suman, R. (2022). Understanding the role of digital technologies in education: A review. Sustainable operations and computers, 3, 275-285

Hohman, F . Kahng,M., Pienta, R. and Chau D. H. (2019) "Visual Analytics in Deep Learning: An Interrogative Survey for the Next Frontiers," in IEEE Transactions on Visualization

Hu, Y. (2021). Effects and acceptance of precision education in an AI-supported smart learning environment. Education and Information Technologies, 27, 2013 - 2037. https://doi.org/10.1007/s10639-021-10664-3.

Hwang, G. J., Xie, H., Wah, B. W., & Gašević, D. (2020). Vision, challenges, roles and research issues of Artificial Intelligence in Education. Computers and Education: Artificial Intelligence, 1, 100001. https://doi.org/10.1016/j.caeai.2020.100001.

Inegbedion, O. (2022). Promoting Lifelong Learning through Capacity Development in Open Educational Resources. Tenth Pan-Commonwealth Forum on Open Learning. https://doi.org/10.56059/pcf10.5424.

Jiang, M. (2023). The Impact and Potential of Educational Technology: A Comprehensive Review. *Research and Advances in Education.* https://doi.org/10.56397/rae.2023.07.05.

Jian, M. (2023). Personalized learning through AI. Advances in Engineering Innovation. https://doi.org/10.54254/2977-3903/5/2023039.

Joshi, D. (2023). Exploring the Impact of Remote Learning and Education Technology on Teaching and Learning Practices. *International Journal For Multidisciplinary Research.* https://doi.org/10.36948/ijfmr.2023.v05i06.8489.

Kamalov, F.; Santandreu Calonge, D.; Gurrib, I. (2023). New Era of Artificial Intelligence in Education: Towards a Sustainable Multifaceted Revolution. Sustainability, 15, 12451. https://doi.org/10.3390/su151612451

Kawahara, Y. (2020). Understanding the underlying algorithms and theories of machine learning. 40-42. https://doi.org/10.21820/23987073.2020.2.40.

Kiong, J. (2023). The Impact of Technology on Education: A Case Study of Schools. *Journal of Education Review Provision*. https://doi.org/10.55885/jerp.v2i2.153.

Kuleto, V., Ilić, M., Dumangiu, M., Ranković, M., Martins, O., Păun, D., & Mihoreanu, L. (2021). Exploring Opportunities and Challenges of Artificial Intelligence and Machine Learning in Higher Education Institutions. Sustainability. https://doi.org/10.3390/su131810424.

Li, S. (2023). The historical evolution of educational technology: from the printing press to online education. OOO "Zhurnal"Voprosy Istorii". https://doi.org/10.31166/voprosyistorii202309statyi2.

Liando, N. V. F., & Tatipang, D. P. (2024). Enlightened Minds: Navigating The Nexus of Artificial Intelligence and Educational Modernization. Penerbit Tahta Media. http://tahtamedia.co.id/index.php/issj/article/view/61 Nykyporets, S. S.

Linn, M. (2003). Technology and science education: Starting points, research programs, and trends. *International Journal of Science Education*, 25(6), 727–758. https://doi.org/10.1080/09500690305017

Luo, Y. (2022). The Impact of Building a National Online Education System on Lifelong Learning. Proceedings of the 2022 3rd International Conference on Mental Health, Education and Human Development (MHEHD 2022). https://doi.org/10.2991/assehr.k.220704.070.

Malik, R. (2023). Impact of Technology-based Education on Student Learning Outcomes and Engagement. 2023 10th International Conference on Computing for Sustainable Global Development (INDIACom), 784-788.

Makarova, E. A., & Makarova, E. L. (2018). Blending pedagogy and digital technology to transform educational environment. *International Journal of Cognitive Research in Science, Engineering and Education:* (IJCRSEE), 6(2), 57-66.

Moemeke, C. D (2023) Integrating Scientific Literacy and Communication in the Curriculum: A Pathway to Bridging the Science-society Gap. Zamfara IJOH 2(1) e-ISSN: 2811-1621www.zamijoh.com.DOI:10.36349/zamijoh.2023.v02i01.001 https://www.zamijoh.com/2023/07/integrating-scientific-literacy-and.html#more. A publication of Faculty of Humanities, Federal University, Gusau, Zamfara state

Morandín-Ahuerma, Fabio (2022).What is Artificial Intelligence? Int. J. Res. Publ. Rev 3 (12):1947-1951.

Nobre, A. (2020). Share knowledge, participate in open education and create oer., 4. https://doi.org/10.37444/ISSN-2594-5343.V4I3.257.

Nykyporets, S. S., & Ibrahimova, L. V. (2023). An empirical analysis of active and interactive pedagogical strategies in the context of distance learning environments: A comparative study. Innovations in the Education of the Future: Integration of Humanities, Technical and Natural Sciences: International collective monograph. Chap. 22: 393-410.

Oancea, R.; Gorski, A.-T.; Gorski, H.; Tudorache, P. (2023) Adaptive Learning Using Artificial Intelligence in e-Learning: A Literature Review. Educ. Sci. 13, 1216. https://doi.org/10.3390/educsci13121216

Owan, V., Abang, K., Idika, D., Etta, E., & Bassey, B. (2023). Exploring the potential of artificial intelligence tools in educational measurement and assessment. Eurasia *Journal of Mathematics, Science and Technology Education.* https://doi.org/10.29333/ejmste/13428.

Partarakis, N.; and Zabulis, X. (2024) A Review of Immersive Technologies, Knowledge Representation, and AI for Human-Centered Digital Experiences. Electronics, 13, 269. https://doi.org/10.3390/electronics13020269

Patero, J. (2023). Integrating Technology in Physics and Math Instruction: A Pedagogical Approach. *International Journal of Advanced Research in Science, Communication and Technology*. https://doi.org/10.48175/ijarsct- 12371.

Polya, G. (1945). How to solve it: A new aspect of mathematical method. Princeton University Press.

Rahmat, A., Kuswanto, H., & Wilujeng, I. (2023). Integrating Technology into Science Learning in Junior High School: Perspective of Teachers. Jurnal Penelitian Pendidikan IPA. https://doi.org/10.29303/jppipa.v9i5.2922.

Ray, S. (2019). A Quick Review of Machine Learning Algorithms. 2019 International Conference on Machine Learning, Big Data, Cloud and Parallel Computing (COMITCon), 35-39. https://doi.org/10.1109/COMITCon.2019.8862451.

Ritella, G. (2017). Open Educational Resources: an Opportunity for Democratic Education?. Civitas educationis. Education, Politics, and Culture, 6, 79-93.

Rizvi, M. (2023). Exploring the landscape of artificial intelligence in education: Challenges and opportunities. 2023 5th International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA), 01-03. https://doi.org/10.1109/HORA58378.2023.10156773

Rizvi, Y.S. and Nabi, A. (2021), "Transformation of learning from real to virtual: an exploratory-descriptive analysis of issues and challenges", Journal of Research in Innovative Teaching & Learning, Vol. 14 No. 1, pp. 5-17. https://doi.org/10.1108/JRIT-10-2020-0052

Salam, H., Çeliktutan, O., Gunes, H., & Chetouani, M. (2023). Automatic Context-Aware Inference of Engagement in HMI: A Survey. IEEE Transactions on Affective Computing. https://doi.org/10.1109/taffc.2023.3278707.

Shameer, K., Johnson, K., Glicksberg, B., Dudley, J., & Sengupta, P. (2018). Machine learning in cardiovascular medicine: are we there yet?. Heart, 104, 1156 - 1164. https://doi.org/10.1136/heartjnl-2017-311198.

Struyf, A., Loof, H., Pauw, J., & Petegem, P. (2019). Students' engagement in different STEM learning environments: integrated STEM education as promising practice?. *International Journal of Science Education*, 41, 1387 - 1407. https://doi.org/10.1080/09500693.2019.1607983.

Tenon, S. R., & Epler, P. (Eds.). (2020). Evaluation of principles and best practices in personalized learning. IGI Global. and Computer Graphics, vol. 25, no. 8, pp. 2674-2693,doi: 10.1109/TVCG.2018.2843369.

Holmes, W and Tuomi, I (2022). State of the Art and practice of AI in Education. *European Journal of Education* 57: 542-570.

UNICEF (2021). Policy guidance on AI for children. Author. https://www.unicef.org/globalinsight/media/2356/file/UNICEF-Global-Insight-policy- guidance-AI-children-2.0-2021.pdf.pdf

Yu, H. (2024) The application and challenges of ChatGPT in educational transformation: New demands for teachers' roles, Heliyon 10(2) https://doi.org/10.1016/j.heliyon.2024.e24289.

Zhai, X., Chu, X., Chai, C., Jong, M., Istenič, A., Spector, M., Liu, J., Yuan, J., & Li, Y. (2021). A Review of Artificial Intelligence (AI) in Education from 2010 to 2020. Complex., 2021, 8812542:1-8812542:18. https://doi.org/10.1155/2021/8812542.