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Impact of Integrating Artificial Intelligence into Science Education: A Systematic Review of Current Literature and Practices

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Abstract
This paper reviews the integration of Artificial Intelligence (AI) in science education, with a particular focus on its impact within the Nigerian educational system. The research identifies key themes, methodologies, and findings from current literature, analyzing how AI affects teaching and learning outcomes in science. It evaluates global practices in integrating AI into science education, comparing developed and developing countries, to provide a balanced view of AI's potential and limitations. In Nigeria, AI adoption is still in its early stages, facing challenges related to inadequate infrastructure, limited teacher training, and issues of equity. The study investigates these barriers, highlighting the disparities between urban and rural educational settings, and assesses how these factors impact student engagement, motivation, and learning outcomes. Additionally, this research examines the different strategies and approaches used globally, exploring how these can be adapted for Nigeria. Based on the findings, the study formulates evidence-based recommendations for policymakers and educators on best practices for integrating AI in science education. These recommendations emphasize the need for equitable and sustainable AI initiatives to ensure that all students, regardless of location or resources, can benefit from AI-enhanced learning experiences. The study aims to inform policy decisions that will foster the responsible and effective use of AI in Nigerian science education

Keywords: Artificial Intelligence, Science Education, Systemic Review, Students, Nigeria

Introduction

One revolutionary technology that is changing many industries, including education, is artificial intelligence (AI). AI has a lot to offer, especially in the field of science education. A revolutionary change in teaching methods and learning objectives is represented by the incorporation of artificial intelligence (AI) into science education. The use of AI to improve educational experiences has attracted a lot of attention as educational institutions around the world work to adjust to the demands of the twenty-first century. The potential of AI to transform science education is especially compelling in Nigeria, where educational challenges like large class sizes, outdated curricula, and a lack of resources still exist. In the context of education, artificial intelligence (AI) refers to the simulation of human intelligence processes by machines, especially computer systems. These processes include learning (the acquisition of information and rules for using it), reasoning (using rules to reach approximate or definite conclusions), and self-correction. Science education includes teaching and learning in the fields of biology, chemistry, physics, and earth sciences. Its goal is to provide students with the scientific knowledge, skills, and attitudes necessary for comprehending the natural world and making informed decisions (National Research Council, 2012). An effective science education encourages critical thinking, problem-solving skills, and a scientific mindset among learners. The role of AI in improving teaching methods is gaining recognition worldwide. Research has shown that integrating AI into science education boosts student engagement, enables personalized learning experiences, and provides real-time feedback (Luckin et al., 2016). For instance, intelligent tutoring systems can analyze students' performance and adjust learning materials to suit their individual needs (VanLehn, 2011). Additionally, AI-powered tools can assist teachers with administrative tasks, allowing them to focus more on teaching and interacting with students.

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Over the years, science education has undergone a significant transformation. The traditional method of rote memorization has gradually given way to inquiry-based learning, which encourages students to actively explore scientific concepts (National Science Teachers Association [NSTA], 2018). This shift aligns well with AI technologies, which can offer interactive simulations and virtual labs, allowing students to experiment with scientific principles in engaging ways. However, several challenges hinder effective science instruction in Nigeria's education system. A shortage of qualified teachers, inadequate infrastructure, insufficient teaching materials, and limited access to modern technology are major barriers (Adetunji & Ojo, 2020). Despite these obstacles, there is growing recognition of the role technology can play in improving learning outcomes. The Nigerian government has launched various initiatives to integrate technology into science education. However, implementation remains inconsistent across different regions and institutions. AI has the potential to bridge some of these gaps by offering scalable solutions that enhance both student engagement and instructional effectiveness.

The integration of AI into science education in Nigeria could lead to significant improvements in learning outcomes. AI-powered tools can help teachers create more personalized learning experiences tailored to students' diverse needs. Adaptive learning platforms, for example, can assess a student's performance in real time and adjust lesson plans accordingly. This individualized approach helps address disparities in student performance caused by unequal access to resources. Additionally, AI can foster collaborative learning environments where students engage in virtual simulations to solve scientific problems. These interactive experiences not only deepen understanding but also develop critical thinking skills essential for scientific inquiry (Baker et al., 2020). Furthermore, AI tools can streamline administrative tasks, giving teachers more time to focus on student engagement. While the benefits of AI in education are promising, there are also concerns among educators and stakeholders. Supporters argue that AI can enhance educational equity by providing high-quality resources to students regardless of their location (Luckin et al., 2016). AI-driven analytics can also help identify struggling students early, allowing timely intervention. However, critics warn that excessive reliance on AI could diminish human interaction in education, making learning feel impersonal (Selwyn & Facer, 2013). There are also growing concerns about data security and privacy, as educational institutions collect more sensitive information on students' performance and behaviors (Zuboff, 2019). Additionally, if access to AI-driven tools is uneven, the technology could unintentionally widen existing educational inequalities rather than bridge them.

Successfully integrating AI into Nigeria's science education system requires a strategic approach that considers local challenges. Teachers must receive proper training not only on using AI tools but also on integrating them effectively into their teaching methods. Professional development programs should equip educators with the skills needed to use technology in a way that complements, rather than replaces, traditional teaching practices. Collaboration between tech companies and educational institutions can also accelerate the development of AI solutions tailored to Nigeria's specific educational needs. These partnerships can help address infrastructure challenges in schools and ensure that AI-driven technologies are both up-to-date and culturally relevant. Beyond its immediate academic benefits, integrating AI into science education prepares students for future careers in an increasingly technology-driven world. As industries evolve with AI and automation, it is crucial to equip students with the skills needed to thrive in this changing landscape (World Economic Forum [WEF], 2020). Incorporating AI into science curricula can help Nigerian students develop the ability to tackle complex scientific problems using cutting-edge technologies. Furthermore, this aligns with global trends emphasizing STEM (Science, Technology, Engineering, and Mathematics) education as a key driver of economic growth. Countries that invest in STEM initiatives gain a competitive edge in the global economy, making Nigeria's focus on technology integration in science education both timely and essential.

Several empirical studies have explored various aspects of AI integration into science education:

i. **Personalized Learning**: A study by Baker et al. (2020) found that adaptive learning platforms utilizing AI significantly improved student engagement and achievement in STEM subjects among middle school students.
ii. **Teacher Perceptions**: Research conducted by Adetunji and Ojo (2020) highlighted Nigerian teachers' perceptions toward integrating technology into their classrooms but noted considerable barriers such as lack of training and infrastructure.
iii. **Impact on Learning Outcomes**: Luckin et al. (2016) reviewed various studies demonstrating how intelligent tutoring systems enhanced learning outcomes across different subjects by providing personalized feedback tailored to individual learner needs.

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There is still little research explicitly addressing how these integrations apply in secondary school environments or rural settings where resources are limited, despite these findings showing positive outcomes from integrating artificial intelligence within educational contexts globally or within specific regions like Africa's higher institutions. While previous research offers insightful information about the integration of technology in STEM fields worldwide or in other Nigerian sectors (Adetunji & Ojo, 2020), empirical studies specifically examining the effects of AI on science education at different levels in Nigerian schools are conspicuously lacking. Furthermore, the majority of research has not looked at how cultural factors affect attitudes towards embracing new technologies, and little is known about teacher training programs that specifically focus on integrating artificial intelligence into current curricula.

The future workforce development of Nigeria is at serious risk if artificial intelligence is not incorporated into science curricula, particularly in terms of training students for occupations that depend more and more on technological competence. Students may graduate without the fundamental skills necessary for success in the face of rapid technological advancements if they are not exposed to contemporary teaching practices that are in line with emerging trends. As a result, even though there is basic knowledge about each of the study's components—artificial intelligence integration, effects on teaching strategies, and the importance of STEM initiatives—further research is desperately needed to examine their combined effects, particularly in the Nigerian educational setting. Closing these gaps will not only greatly improve educational frameworks but also increase economic competitiveness in key industries, which will benefit society as a whole. Therefore, this study seeks to investigate impact of integrating artificial intelligence into science education in Nigerian educational system by using a systematic review of current literature and practices.

Statement of the Problem

A revolutionary chance to improve teaching and learning outcomes is presented by the incorporation of artificial intelligence (AI) into science education. Nonetheless, a systematic review is required due to the substantial gaps found in the current literature. A thorough examination of the actual implementation practices in various educational contexts is lacking, especially in developing nations like Nigeria, despite the fact that numerous studies highlight the potential advantages of AI, such as personalised learning and increased student engagement (Luckin et al., 2016; Baker et al., 2020).

Also, prior research frequently ignores the wider implications for curriculum design and pedagogical strategies in favour of concentrating on isolated case studies or particular AI applications (Adetunji & Ojo, 2020). The knowledge of how AI can be successfully incorporated into science education holistically is limited by this disjointed approach. Additionally, concerns regarding equity, access, and teacher preparedness remain underexplored, raising questions about the sustainability of AI initiatives in educational settings. It is against this background that this study aims to fill these gaps by systematically reviewing current literature and practices related to the integration of AI in science education, providing insights that can inform policy and practice while addressing the unique challenges faced by educators in Nigeria.

Aim and Objectives of the Study

The main purpose of this study is to examine the impact of integrating artificial intelligence into science Education in Nigerian educational system by using a systematic review of current literature and practices.

Specifically, the study seeks to:

i. systematically review existing literature on the integration of Artificial Intelligence in science education, identifying key themes, methodologies, and findings that highlight the impact of AI on teaching and learning outcomes;
ii. evaluate the current practices and strategies employed in integrating AI into science education across various educational contexts, focusing on both developed and developing countries;
iii. investigate the challenges and barriers faced by educators and institutions in implementing AI technologies within science curricula, including issues related to training, infrastructure, and equity;
iv. assess how the integration of AI affects student engagement, motivation, and learning outcomes in science education, comparing these effects across different educational settings.
v. formulate evidence-based recommendations for policymakers and educators on best practices for effectively integrating AI into science education, ensuring that such initiatives are sustainable and equitable.

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Literature Review- Artificial Intelligence in Science Education

Teaching strategies and learning opportunities have been completely transformed by the introduction of Artificial Intelligence (AI) into science education. These days, AI tools are being used to improve student engagement in scientific subjects, offer dynamic assessment strategies, and improve personalised learning. Artificial intelligence (AI) tools in the classroom, like automated grading and intelligent tutoring systems, enable teachers to better meet the needs of each individual student, creating a more personalised learning environment (Zawacki-Richter et al., 2019). AI's capacity to facilitate individualised learning is a key benefit for science education. By providing tailored content and feedback, intelligent systems can adjust to students' learning preferences and skill levels (Woolf, 2020). This has proven particularly beneficial in science education, where students often face complex concepts that require tailored instruction. By analyzing a student's learning patterns, AI systems can predict their struggles and recommend specific resources or practice exercises, thereby improving their overall understanding of the subject matter (Holmes et al., 2019).

AI also makes learning environments more dynamic and interactive. Without the limitations of conventional labs, students can experiment with scientific ideas in a risk-free environment thanks to virtual labs, simulations, and AI-driven software (Luckin, 2017). In addition to aiding students in visualising abstract scientific theories, these resources promote inquiry-based learning, which allows students to interact with the content in a more independent and exploratory way (Spector et al., 2016). In chemistry or biology classes, for instance, AI-powered simulations allow students to perform virtual experiments in which they can change variables and see results instantly, enhancing their conceptual understanding (Hwang et al., 2020). By giving teachers instant feedback and lessening their workload, AI also enhances assessment techniques. Real-time evaluation of student responses by AI-driven analytics and automated grading systems can reveal areas of strength and weakness (Baker & Smith, 2019). By doing this, teachers can spend less time on administrative duties and concentrate on offering more specialised support. Furthermore, these AI tools provide a more data-driven method of assessing student performance, allowing for assessments that are more accurate and equitable (Bynum, 2020).

AI has many benefits, but its application in science education raises questions about access and equity. Since students in underprivileged areas might not have access to AI-driven technologies, their integration could make the digital divide worse (Williamson et al., 2020). Furthermore, there are ethical questions surrounding the use of AI in educational settings, specifically with regard to algorithmic bias and data privacy (Selwyn, 2019). To guarantee that AI fosters inclusive and equitable learning environments, even though it has a lot to offer science education, its application needs careful thought. By providing individualised learning experiences, increasing student engagement, and expediting assessment procedures, artificial intelligence (AI) holds the potential to revolutionise science education. But educators and legislators have to deal with issues of ethics and equity to fully harness the potential of AI in education.

The Integration Of Artificial Intelligence in Science Education by Identifying Key Themes, Methodologies, And Findings That Highlight The Impact Of AI on Teaching And Learning Outcomes

Researchers and educators from all over the world have been paying close attention to the incorporation of artificial intelligence (AI) into science education. Numerous important themes, approaches, and conclusions that demonstrate the revolutionary influence AI has on teaching and learning outcomes are revealed by a thorough analysis of the body of current literature. It is commonly known that artificial intelligence (AI) can improve individualised instruction, create dynamic learning environments, and expedite evaluation procedures. Access, ethics, and equity issues still exist, though, particularly when considering developing nations like Nigeria.

Developments in machine learning, natural language processing, and data analytics have propelled the integration of AI in science education globally. AI's potential to develop intelligent tutoring programs that adjust to the needs of each individual student has been studied. In their 2019 systematic review of AI applications in higher education, for example, Zawacki-Richter et al., highlighted how AI facilitates personalised learning by examining students' learning styles and offering customised feedback. Woolf (2020) echoes this theme of personalisation by emphasising AI's capacity to design customised learning pathways, meeting the needs of the diverse student body in challenging subjects like chemistry and physics.

The use of AI-powered simulations and virtual labs in science education is another major theme. Students can interact with intricate scientific ideas in a dynamic, risk-free setting thanks to these resources (Holmes et al., 2019). According

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to Hwang et al. (2020), AI-driven simulations in biology and chemistry give students practical experience and enhance their comprehension of abstract concepts by enabling them to see and control variables in real-time experiments. These studies demonstrate how AI can make learning more interactive and exploratory, which can greatly increase student engagement and retention of scientific knowledge.

AI has also changed how assessments are conducted. According to Baker and Smith (2019), real-time feedback is provided by AI-powered grading systems and analytics tools, freeing up teachers to concentrate on more important facets of instruction, like fostering students' cognitive growth. These tools facilitate the early detection of learning gaps, allowing for prompt interventions that enhance learning results.
Although it is still in its early phases, artificial intelligence (AI) in science education has made significant strides in Nigeria in recent years. The opportunities and difficulties associated with integrating AI in Nigerian education have been the subject of a few studies. An exploratory study on the potential of AI to improve science instruction in secondary schools in Nigeria was carried out by Okoye and Eze (2021). Their findings suggest that while there is growing awareness of AI's benefits, its adoption is hampered by infrastructural challenges, such as inadequate internet connectivity, limited access to computers, and a lack of trained personnel.

Despite these challenges, there have been pilot initiatives aimed at integrating AI in Nigerian science classrooms. For instance, a study by Aderinoye and Ogunniyi (2020) on the use of AI-based learning management systems in Lagos schools found that AI tools enhanced student performance in science subjects, particularly in personalized learning environments. However, the authors also pointed out the issue of digital inequality, where students in rural areas had little to no access to these AI-driven tools, thus exacerbating the digital divide. Additionally, AI in Nigerian science education has sparked debates regarding its ethical implications. Issues such as data privacy, algorithmic bias, and the potential replacement of human teachers by AI have been discussed extensively. According to Oloyede (2022), while AI offers numerous benefits, it is crucial for policymakers to establish guidelines that address these ethical concerns, ensuring that AI implementation supports, rather than undermines, the role of teachers. The methodologies used to study AI integration in science education are diverse. Global studies often employ systematic reviews, experimental designs, and mixed-methods approaches to evaluate AI's impact on learning outcomes. For instance, the review by Zawacki-Richter et al. (2019) synthesized over 200 studies, using a systematic review methodology to identify trends and gaps in AI research within higher education. Similarly, Holmes et al. (2019) used an experimental design to test the efficacy of AI-driven tutoring systems, demonstrating significant improvements in student performance.

Because AI adoption in Nigeria is still in its infancy, the majority of studies have used qualitative and case study methodologies. For instance, Okoye and Eze (2021) evaluated opinions about AI in education through semi-structured interviews with educators and legislators. These studies frequently point out the socioeconomic and infrastructure constraints that prevent AI from being fully implemented in science education, even though it has the potential to enhance learning outcomes. A comprehensive analysis of the literature on the use of AI in science education, both internationally and in Nigeria, identifies important themes like enhanced assessment techniques, personalised learning, and interactive engagement through simulations. Through the creation of personalised learning experiences and the simplification of administrative duties, artificial intelligence has greatly improved teaching and learning outcomes worldwide. In Nigeria, however, the adoption of AI is constrained by infrastructural and ethical challenges, although pilot projects show promise. Moving forward, both global and Nigerian educational systems must address issues of equity, access, and ethics to fully harness the benefits of AI in science education.

Current Practices and Strategies in Integrating AI into Science Education: A Global and Nigerian Perspective
A rapidly developing trend in many educational contexts is the incorporation of artificial intelligence (AI) into science education. Both developed and developing nations are using AI-based techniques to improve teaching and learning. Although developed nations frequently set the standard for advanced AI deployment, developing countries—like Nigeria—face particular opportunities and challenges when it comes to implementing these technologies. As a result, the key practices and strategies used to integrate AI into education vary greatly across regions. Personalised learning platforms, virtual labs, and intelligent tutoring systems have been the main goals of AI integration in science education in developed nations. According to Holmes et al. (2019), these technologies enable adaptive learning, in which AI systems evaluate each student's performance to tailor lessons and offer pertinent feedback. AI-powered platforms such as Carnegie Learning, for instance, offer individualised instruction in the US by evaluating a student's strengths and weaknesses in real time, allowing teachers to provide more efficient, tailored support (Baker & Smith, 2019).

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Furthermore, nations like Finland, the UK, and Japan have advanced in their use of AI for assessment and classroom management. Automatic assignment grading by AI-based technologies relieves teachers of tedious duties and enables them to concentrate more on the calibre of instruction. In order to help students track their progress and enhance their comprehension of scientific concepts, Finland's educational system places a strong emphasis on the use of AI-driven formative assessments that provide immediate feedback (Luckin, 2017). According to Zawacki-Richter et al. (2019), these tools also help teachers by offering comprehensive analytics on student performance, which enables data-driven decision-making in instructional planning and curriculum design.
In developed nations, students can participate in scientific experiments in a virtual setting through the use of AI-powered simulations and virtual labs. In addition to saving money on conventional lab setups, this enables students to carry out experiments that might otherwise be too costly or risky to duplicate in the real world (Hwang et al., 2020). These methods are especially common in nations like South Korea, where national science curricula incorporate AI-based virtual labs to encourage experiential learning free from the limitations of tangible materials (Williamson et al., 2020). "

AI integration into science education is still in its infancy in developing nations, where the majority of efforts are focused on pilot projects and experimental implementations. For example, the main goals of AI integration in Nigeria are to increase educational access and improve learning outcomes in areas with limited resources. However, there are major obstacles to the widespread use of AI in Nigerian classrooms due to a lack of infrastructure, such as dependable internet access (Aderinoye & Ogunniyi, 2020). Attempts to integrate AI into Nigerian education are increasing in spite of these obstacles. Addressing learning gaps in science subjects has shown promise with the use of AI-powered educational software. Okoye and Eze (2021) investigated AI-based learning systems in secondary schools in Nigeria and discovered that, despite their limited application, AI tools greatly enhanced student performance by providing individualised learning opportunities. Rural schools are left behind by these tools, which are frequently concentrated in urban areas where schools have better access to technological infrastructure. Some educational initiatives in Nigeria are using mobile-based AI tools to get around these obstacles because they require less infrastructure than traditional computer-based systems. These mobile platforms use AI to provide personalized learning content and assessments for students, allowing for a more equitable distribution of educational resources across different regions (Oloyede, 2022). However, the success of these strategies depends on addressing systemic issues such as teacher training, as many educators lack the necessary skills to effectively use AI technologies in the classroom.

Enhancing personalised learning is a common approach to integrating AI in both developed and developing nations. AI's adoption in science education is thought to be largely driven by its capacity to adjust to the unique needs of each student, enabling more specialised instruction and enhancing student performance and engagement (Zawacki-Richter et al., 2019). Additionally, science education is becoming more interactive and accessible through the use of AI tools that encourage experiential learning through virtual labs and simulations. But there are still difficulties, particularly in developing nations like Nigeria. The successful implementation of AI tools in schools is hampered by infrastructure constraints, such as erratic internet and electricity supply (Aderinoye & Ogunniyi, 2020). Additionally, there is a clear digital divide between rural and urban areas, with students in rural schools frequently lacking access to AI-based learning tools (Okoye & Eze, 2021). The methods and approaches used in developed and developing nations to incorporate AI into science education differ greatly. With sophisticated AI systems that streamline assessment, personalise learning, and increase engagement through simulations, developed countries are setting the standard. On the other hand, developing nations like Nigeria are still in the early phases of implementing AI, concentrating on removing obstacles related to infrastructure and expanding educational opportunities. While AI holds great promise for transforming science education globally, its effective implementation in developing countries will require significant investments in infrastructure, teacher training, and policy support.

Challenges and Barriers to Implementing AI Technologies in Science Education: A Global and Nigerian Perspective

Significant improvements in student engagement, individualised learning, and effective teaching strategies are anticipated when artificial intelligence (AI) is incorporated into science education. However, there are many obstacles to overcome when integrating AI technologies into science curricula, and these obstacles differ depending on where you live. The successful application of AI in education is hampered globally by problems with infrastructure, equity, and teacher preparation. These issues are made worse in developing nations like Nigeria by a widening digital divide, poor policy frameworks, and restricted access to technology resources.

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Training and Teacher Preparedness

The absence of proper teacher preparation is one of the main obstacles to integrating AI into science curricula around the world. Teachers frequently lack the expertise needed to successfully incorporate AI tools into their lessons. According to a Holmes et al. (2019) study, educators in the US and Europe voiced reservations about their capacity to utilise AI-based resources like virtual labs and intelligent tutoring systems. There is a substantial skills gap as a result of the quick speed at which AI is developing surpassing the professional development opportunities accessible to educators (Zawacki-Richter et al., 2019).

The issue of teacher readiness is even more significant in Nigeria. The majority of Nigerian teachers, according to Okoye and Eze (2021), had little to no experience with digital technologies, much less sophisticated AI tools. The resources and training programs needed to successfully integrate AI into science curricula are not readily available to many Nigerian educators. Since even the most sophisticated AI tools require proficient users to optimise their benefits, this teacher training gap undercuts AI's potential to enhance science education outcomes.

Infrastructure Challenges

The availability of sufficient infrastructure, such as dependable internet access, electricity, and technological tools, is also essential for the integration of AI in science education. The fundamental infrastructure required to support AI-based learning platforms and tools is available to schools in many developed nations. But problems still exist even in these areas. For example, Williamson et al. (2020) pointed out that although schools in the US and the UK have invested heavily in AI, the adoption of AI is still hampered by differences in internet access between urban and rural areas. One of the biggest obstacles to the use of AI in education in Nigeria is the country's inadequate infrastructure. High-speed internet and dependable electricity are essential for AI tools to work properly, but many Nigerian schools, especially those in rural areas, lack these resources (Aderinoye & Ogunniyi, 2020). Furthermore, the cost of acquiring the necessary hardware, such as computers and servers, is prohibitive for many educational institutions. This has led to a situation where only a small percentage of schools in urban centers can implement AI technologies, leaving a large portion of the student population without access to these educational innovations (Oloyede, 2022).

Equity and the Digital Divide

In the global conversation about AI in education, equity is a major concern. Even though AI has the potential to make high-quality education more accessible to all, its application frequently makes already-existing disparities worse. Holmes et al. (2019) contend that because they lack access to the required infrastructure and resources, students from underprivileged families and marginalised communities are less likely to gain from AI technologies. Students from wealthy schools are more likely to benefit from AI-driven personalised learning in many developed nations, while students from underfunded schools continue to be denied these opportunities. The digital divide in Nigeria is glaring. While schools in rural and underserved areas continue to face significant disadvantages, schools in urban areas, especially in states like Lagos and Abuja, have started experimenting with AI in science education. The gap between schools with and without access to AI-based tools was brought to light by Okoye and Eze (2021), who pointed out that this gap exacerbates already existing educational disparities. Furthermore, the unequal distribution of AI benefits is exacerbated by the digital skills gap between teachers and students, since those in wealthier areas are more likely to receive the support and training needed to use these technologies.

Policy and Ethical Considerations

The lack of explicit ethical standards and policy frameworks presents another difficulty when integrating AI into science education. Data privacy, algorithmic bias, and the possible dehumanisation of the learning process are just a few of the ethical concerns that governments and educational institutions around the world are battling with in relation to AI in education (Selwyn, 2019). These issues are crucial to the effective integration of AI technologies, but they are frequently overshadowed in developing nations like Nigeria by more pressing issues like infrastructure and training. Oloyede (2022) highlights the necessity of strong regulations in Nigeria that deal with the moral application of AI in the classroom. Schools and other institutions may use AI tools without giving enough thought to concerns like student data privacy and potential biases in AI algorithms if there are no clear guidelines in place. The equitable and long-term integration of AI in Nigerian education may be hampered by this lack of policy coherence. Globally, there are several obstacles to integrating AI in science education, such as insufficient training for teachers, limited infrastructure, and equity concerns. Lack of access to essential resources, the growing digital divide, and the lack of comprehensive policy frameworks all exacerbate these issues in developing nations like Nigeria. Addressing these barriers will require concerted efforts from governments, educational institutions, and stakeholders to ensure that AI technologies can fulfill their potential to transform science education for all learners.

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The Impact of AI on Student Engagement, Motivation, and Learning Outcomes in Science Education Across Different Educational Systems

Learning outcomes, motivation, and student engagement have all been impacted by the revolutionary tools that artificial intelligence (AI) has brought to science education. However, these effects differ greatly depending on the educational context, from classrooms with limited resources in developing nations like Nigeria to technologically advanced settings in developed nations. According to research, artificial intelligence (AI) has enormous potential to improve educational experiences, but how well it is applied in particular educational contexts will determine how effective it is.

AI and Student Engagement

Because AI tools make learning more personalised and interactive, they have been shown to increase student engagement in science education. AI-powered tools like virtual reality (VR) environments and intelligent tutoring systems (ITS) give students practical experience in simulated scientific experiments in high-tech learning environments. According to Holmes et al. (2019), these technologies give students the opportunity to engage with difficult scientific ideas in immersive ways that are not possible in conventional classroom settings. AI is used, for instance, by platforms such as ALEKS and Smart Sparrow in the US to modify content in real-time to each student's unique needs. This keeps students interested by providing challenges that are appropriate for their skill level (Zawacki-Richter et al., 2019). However, the effect of AI on student engagement is less noticeable in settings with less technological sophistication, such as many Nigerian rural schools. The ability to fully utilise AI technologies in the classroom is hampered by limited access to the required infrastructure, such as computers, dependable internet, and electricity (Aderinoye & Ogunniyi, 2020). When AI is available, like in cities, research indicates that its application has raised student engagement by providing them with interactive science learning opportunities that aren't possible with conventional textbook-based instruction (Okoye & Eze, 2021). Despite these advantages, many students in developing contexts are unable to fully utilise AI's engagement-enhancing capabilities due to limited access.

AI and Student Motivation

AI's influence on student motivation is intimately related to its capacity to customise learning. AI tools can greatly boost student motivation by making learning feel more relevant and accessible by providing individualised pathways through scientific content and customised feedback (Luckin, 2017). For example, students in developed nations who use AI-powered learning platforms report higher levels of motivation because these platforms can adapt task difficulty to meet individual learning needs and offer immediate, constructive feedback (Baker & Smith, 2019). This is particularly helpful in science education, as traditional teaching methods can demotivate students when dealing with complex subjects. However, it is more challenging to reap the motivational benefits of AI in developing nations. In Nigeria, for instance, students in rural areas are left with traditional, non-interactive teaching methods that can lower motivation, while some students in urban areas benefit from personalised learning experiences due to the unequal distribution of AI tools (Oloyede, 2022). Okoye and Eze (2021) contend that because AI is only occasionally used in Nigerian classrooms, many students are unable to benefit from its motivational effects, growing the divide between high-achieving, driven students in well-resourced schools and their peers in underfunded ones.

AI and Learning Outcomes

AI's impact on learning outcomes is perhaps its most widely researched benefit, particularly in science education. In developed settings, AI has been shown to significantly improve student performance in science subjects. According to a meta-analysis by Zawacki-Richter et al. (2019), AI-powered systems—especially ITS—improve learning outcomes by providing students with real-time feedback loops, personalised instruction, and ongoing assessment. Students in science courses routinely perform better than their peers in non-AI-assisted educational settings in nations like South Korea, where AI is completely incorporated into the national curriculum (Hwang et al., 2020). Aderinoye and Ogunniyi (2020) suggest that although AI has the potential to improve science learning outcomes across Nigeria, the current lack of infrastructure and teacher training means that its benefits remain confined to a small subset of students. In contrast, the impact of AI on learning outcomes in developing countries is still limited by infrastructure and access disparities. In Nigeria, studies show that students who have access to AI-powered tools in urban schools perform better in science subjects than those in rural schools without such access (Okoye & Eze, 2018). By enhancing learning outcomes, motivation, and student engagement, artificial intelligence (AI) holds the potential to completely transform science education. The impacts of AI are more noticeable in developed educational environments with more easily accessible infrastructure and resources, where students gain from individualised instruction and hands-on

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experience with scientific ideas. However, there are many obstacles to integrating AI in developing nations like Nigeria, especially when it comes to infrastructure and fair access. Consequently, the benefits of AI on motivation, engagement, and learning outcomes are less consistent, underscoring the necessity of focused efforts to remove these obstacles and guarantee that all students can take advantage of science education enhanced by AI.

Summary

Through a methodical review of current research and practices, this study examines the effects of incorporating artificial intelligence (AI) into science education in Nigeria. It compares these in Nigerian and international contexts while examining important themes, approaches, and findings regarding the use of AI to improve teaching and learning outcomes. Focusing on how AI tools enhance student engagement, motivation, and learning outcomes, the study assesses current approaches and strategies for integrating AI into science education in both developed and developing nations. Challenges like poor infrastructure, insufficient training for teachers, and equity concerns are examined, particularly in the Nigerian educational system where obstacles like the digital divide and restricted access to technology are common. The study also identifies the differences between schools with adequate funding and those with inadequate funding, and evaluates how well AI can enhance science instruction, especially in diverse educational environments. Lastly, the study provides educators and policymakers with evidence-based suggestions for the fair and sustainable incorporation of AI into science curricula. In order to improve learning outcomes in Nigeria and elsewhere, these recommendations seek to address obstacles and facilitate the effective adoption of AI technologies.

Conclusion

To sum up, incorporating artificial intelligence (AI) into science instruction has the potential to revolutionise the field, especially in terms of improving teaching and learning results. This study conducted a thorough review of existing literature and practices, emphasising important themes and approaches that show how AI improves academic performance, student motivation, and engagement. The adoption of AI has advanced significantly in developed countries, but developing countries like Nigeria face obstacles like poor infrastructure, a lack of teacher preparation, and equity issues. The study emphasises that in order to fully reap the benefits of AI in Nigerian science education, these issues must be resolved. Furthermore, AI's capacity to customise educational experiences shows promise but necessitates cautious application. Evidence-based suggestions are developed in light of the findings to help educators and legislators ensure the fair, long-lasting, and successful integration of AI. In order to improve educational outcomes in Nigeria and elsewhere, the study urges cooperation in removing obstacles and promoting the adoption of AI. Nigeria can establish an AI-enhanced educational system that equips students with the skills need to succeed in science and technology fields and prepares them for the demands of the modern world with the correct investments and policies.

Suggestions

Based on the arguments explored by the researchers, the following suggestions were made:

1. The government must offer thorough training programs to give teachers the know-how to incorporate AI tools into science curricula. Teachers will maintain their proficiency in utilising AI technologies to improve student learning through ongoing professional development.
2. To ensure equitable access to AI tools in science education, all levels of government must prioritise enhancing the technological infrastructure in schools, particularly in rural and underserved areas. This includes ensuring that schools have adequate electricity and dependable internet access.
3. Encourage fair AI adoption by developing regulations that will ensure all schools, irrespective of location or financial means, have access to AI tools in an effort to close the digital divide. This involves offering reasonably priced software and hardware to fill in the gaps in the supply of resources.
4. To create science curricula that successfully integrate AI, focussing on experiential learning and individualised instruction while adhering to national education goals, it is necessary to work with educational specialists to create AI-Inclusive Curricula.
5. To promote responsible and open use of AI technologies in schools, Ethical and Data Privacy Guidelines must be established. These guidelines should address ethical issues pertaining to AI in education, such as algorithmic bias and student data privacy.

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