

**PERCEIVED INFLUENCE OF AI-INTEGRATED SCIENCE EDUCATION ON
SUSTAINABLE DEVELOPMENT OUTCOMES IN PORT HARCOURT
METROPOLIS**

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ABSTRACT

This study examines the perceived influence of AI-integrated science education on sustainable development outcomes in Port Harcourt Metropolis. In line with the aim of the study, two objectives, two research questions and two hypotheses were formulated to guide the study. The study adopted a descriptive research design, the population for the study consisted of 1,899 senior secondary school teachers, drawn from 39 public senior secondary schools in Port Harcourt Metropolis. A purposive sampling technique was employed to select 400 participants with relevant experience and exposure to AI tools. Data were collected through a structured questionnaire designed to capture perceptions of science teachers on AI's contribution to sustainable development, effectiveness in teaching and learning, adoption barriers, and long-term prospects. Mean and standard deviation were used to answer the research questions while t-test was used to test the hypotheses at 0.05 level of significance. Findings of this study revealed that teachers in Port Harcourt Metropolis strongly perceive AI-integrated science education as contributing significantly to sustainable development outcomes, the study also revealed that inadequate infrastructure, lack of teacher training, high costs of acquiring AI technologies, and limited access to digital devices by students remain the most pressing barriers to AI adoption in Port Harcourt science classrooms. Based on the findings the study recommended among other that; The national curriculum should incorporate AI and digital learning tools in science subjects, government and stakeholders should invest in digital infrastructure such as devices, internet access, and power supply.

KEYWORDS: Artificial Intelligence, Science Education, and Sustainable Development.

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INTRODUCTION

A key component of national development is science education, which gives students the analytical, critical thinking, and problem-solving abilities needed to spur innovation and tackle challenging global concerns. It is impossible to overestimate the importance of science education for sustainable development in a time of climate change, environmental degradation, and rapid technological advancement. As a new transformational technology, artificial intelligence (AI) has the ability to completely change how scientific education is delivered by making it more data-driven, individualized, and flexible enough to meet the demands of a wide range of learners. It makes it possible to create dynamic learning environments where students' conceptual understanding and application of scientific information are improved via simulations and real-time feedback (Luckin et al., 2016).

Traditional science education systems around the world, especially in developing nations like Nigeria, are finding it difficult to keep up with the demands of contemporary pedagogical approaches and sustainable development objectives. Effective science education is nevertheless hampered by problems like out-of-date curricula, packed classrooms, a lack of instructional tools, and underqualified teachers. By offering scalable solutions that increase the scope and calibre of science education across many contexts, AI-powered tools like virtual labs, intelligent tutoring systems, and automated grading platforms can close these gaps (Holmes et al., 2019). Schools may lessen their reliance on physical infrastructure while still conducting rigorous scientific research and experimentation by incorporating AI into the classroom.

Additionally, the use of AI in science education supports the goals of Sustainable Development Goals 4 and 9, which highlight accessible and equal quality education and innovation and resilient infrastructure, respectively. AI-driven platforms, for example, can precisely assess student progress, offer remedial courses, and detect learning flaws early. By ensuring that no student is left behind, this data-centric strategy supports national development initiatives and advances educational equity. Additionally, using predictive analytics, AI can help school administrators and legislators make well-informed decisions, which will ultimately lead to more effective resource allocation and educational planning (Zawacki-Richter et al., 2019).

But there are certain difficulties in incorporating AI into science instruction in Nigeria. Significant obstacles include a lack of infrastructure, teachers' lack of digital literacy, and the high expense of implementing AI. Furthermore, considerable consideration must be given to ethical issues pertaining to algorithmic bias, data privacy, and the dehumanization of educational experiences. Notwithstanding these difficulties, if AI is used strategically, its potential advantages exceed its drawbacks. In order to adjust to AI-enhanced instructional models, educators must get professional development and training in addition to building a strong digital infrastructure (OECD, 2021). AI-integrated scientific education offers a promising way ahead as Nigeria looks to improve its educational results and meet its sustainable development aspirations. Nigerian schools can make science instruction more interesting, effective, and inclusive by utilizing AI's capability. In addition to creating a society that is scientifically educated, this change will produce a generation that can address urgent domestic and international issues. AI has the potential to be a key driver of sustainable growth in Nigerian education with the right policy frameworks, stakeholder collaboration, and teacher training investment (UNESCO, 2022).

STATEMENT OF THE PROBLEM

The adoption of Artificial Intelligence (AI) in education has emerged as one of the most remarkable innovations of the 21st century, with the potential to transform teaching and learning across different fields. Within science education, AI offers possibilities such as individualized learning experiences, intelligent feedback systems, virtual experiments, and interactive problem-solving platforms that can greatly improve student engagement and academic outcomes. Globally, studies highlight that AI-supported learning promotes innovation, analytical thinking, and creativity—skills that directly support the pursuit of

sustainable development. However, the extent to which these benefits are achieved is largely influenced by factors such as availability of infrastructure, teacher competence, access to digital tools, and social attitudes toward technology.

In Port Harcourt Metropolis, science education still struggles with long-standing issues including poorly equipped laboratories, overcrowded classrooms, inadequate teaching resources, and limited application of modern technologies. These constraints often result in poor academic performance and limit students' ability to address real-life challenges in areas such as health, environment, energy, and technology sectors that are vital to achieving sustainable development. Although AI integration could help address these gaps, its use in secondary schools across the metropolis is still uncertain and insufficiently documented.

The Sustainable Development Goals (SDGs) highlight the importance of quality education (SDG 4), infrastructure and innovation (SDG 9), sustainable cities and communities (SDG 11), and climate action (SDG 13). Science education serves as a key driver for the achievement of these goals, but without incorporating emerging technologies like AI, students may be ill-prepared to make meaningful contributions to sustainable development initiatives. This creates a need to examine how AI-supported science education can influence learners' competencies in solving societal challenges within Port Harcourt.

Although global interest in AI for education is growing, little evidence exists in Nigeria—and particularly in Rivers State—regarding its role in equipping students with the knowledge, attitudes, and problem-solving skills required for sustainability. Current research mainly addresses general ICT integration in schools, overlooking the specific opportunities and difficulties associated with AI in science education. This lack of localized studies makes it difficult for decision-makers, teachers, and other stakeholders to design effective policies and programs that align AI-driven education with sustainable development objectives. Equity also remains a pressing concern. In Port Harcourt, inequalities in digital access mean that while some schools may be able to adopt AI innovations, others could be excluded, thereby worsening educational and social divides. If these issues are not carefully examined, the benefits of AI in science education may remain untapped, limiting its potential contribution to sustainable development in the region.

For this reason, it becomes essential to investigate the perceived impact of AI-based science education on sustainable development outcomes within Port Harcourt Metropolis. Such an inquiry will provide valuable evidence that can inform educators, curriculum developers, policymakers, and community stakeholders in effectively applying AI for better science learning and long-term societal advancement.

AIM AND OBJECTIVES OF THE STUDY

The aim of this study is to examine the perceived influence of AI-integrated science education on sustainable development outcomes in Port Harcourt Metropolis. Specifically, the study seeks to:

1. Investigate the perceived contributions of AI-integrated science education to the attainment of sustainable development outcomes in Port Harcourt Metropolis.
2. Examine the challenges and barriers affecting the adoption and effective use of AI technologies in science classrooms in Port Harcourt.

RESEARCH QUESTIONS

The following Research questions guided the study

1. To what extent is AI-integrated science education perceived to contribute to sustainable development outcomes in Port Harcourt Metropolis?

2. What are the challenges and barriers to the adoption and effective use of AI technologies in science classrooms in Port Harcourt Metropolis?

HYPOTHESES

H0₁ AI-integrated science education has no significant perceived contribution to sustainable development outcomes in Port Harcourt Metropolis.

H0₂ There are no significant challenges and barriers to the adoption and effective use of AI technologies in science classrooms in Port Harcourt Metropolis.

SIGNIFICANCE OF THE STUDY

This study is vital for the following reasons:

By promoting educational changes, improving teaching strategies, and assisting with evidence-based decision-making, artificial intelligence (AI) is having a big impact on science education. AI guarantees that scientific education stays relevant in a world that is becoming more technologically advanced by assisting in the development of policies and instructional practices. It improves curriculum design, teacher preparation, and resource management by providing educators and policymakers with empirical facts to help them make well-informed decisions. As a result, the educational system becomes more efficient, responsible, and flexible, able to accommodate students' changing requirements.

Additionally, AI fosters creativity by bringing individualized, interactive teaching resources that improve students' interest and understanding of scientific ideas. By offering adaptive learning solutions that empower various learners, particularly in underprivileged parts of Nigeria, it also advances educational equity. AI gives pupils the essential 21st-century abilities required for economic growth and technological advancement by coordinating science education with national development goals. As a result, AI not only improves educational opportunities but also helps create a workforce with the necessary skills for Nigeria's long-term growth.

CONCEPTUALIZATION

Artificial Intelligence (AI)

Artificial Intelligence (AI) in education involves the application of data-driven technologies and machine learning techniques within teaching and learning processes, aimed at enhancing instructional delivery and simulating certain cognitive abilities of human teachers. These technologies are designed to support reasoning, problem-solving, and adaptive learning, thereby addressing the diverse needs of learners. In practice, AI tools in the classroom include digital tutors, chatbots, and virtual learning assistants that provide guidance, feedback, and responses to learners' inquiries. Such innovations minimize overdependence on the teacher while promoting learner autonomy, particularly in e-learning and blended education contexts (Adenugba, 2024).

AI's capacity to customize learning experiences to meet the demands of each individual learner is one of its main educational contributions. AI-powered systems evaluate learner data in real-time, such as quiz answers or task completion time, and modify content in response, in contrast to traditional classroom approaches where instruction is frequently standardized. By delivering content in a structure and order that suit their learning style and pace, this method—known as adaptive learning—improves students' comprehension. In addition to raising student enthusiasm and engagement, this individualized strategy helps close success disparities, particularly for students with learning difficulties or varying cognitive

abilities (Holmes *et al.*, 2019). AI facilitates data-informed decision-making, which makes it a significant instrument in educational administration outside of the classroom. AI is being used more and more by educational institutions to carry out duties including class schedule optimization, instructor performance evaluation, and at-risk kid identification. For instance, predictive analytics can predict a student's chances of succeeding or failing in particular classes, which helps direct interventions like tutoring or counselling. Policymakers can also create policies that are responsive to current educational needs and better effectively distribute resources by examining trends across districts or schools. Institutional accountability and openness are improved by this proactive use of data (Zawacki-Richter *et al.*, 2019).

Science Education

Teaching scientific concepts, theories, and procedures in an organized and methodical manner is known as science education. From elementary school to tertiary education, it exposes students to fundamental ideas in disciplines including biology, chemistry, physics, and earth sciences. The objective is to cultivate logical reasoning in pupils while expanding their knowledge of facts, theories, and laws related to the natural world. The scientific method a methodology that prioritizes observation, hypothesis formulation, investigation, and data interpretation is fundamental to science education. This approach helps students develop their critical thinking skills, challenge presumptions, and draw conclusions based on factual data (Lederman, 2007).

Effective science education places a strong emphasis on inquiry-based learning and problem-solving techniques in addition to material understanding. Students participate in group projects, fieldwork, and laboratory experiments that mimic actual scientific problems rather than merely absorbing material. These active learning strategies foster higher-order cognitive abilities and improve conceptual understanding. Such environments foster scientific curiosity and resilience by teaching students how to conceive questions, test variables, analyze data, and communicate findings. Additionally, collaborative learning experiences foster communication and teamwork, two abilities that are becoming more and more crucial in diverse scientific professions (Bybee, 2013). Additionally, science education has a profound impact on how nations develop economically and technologically. People who are scientifically knowledgeable are better able to make decisions on innovation, energy, health, and the environment. Improving science education can aid in addressing urgent problems like environmental degradation, disease outbreaks, and food insecurity in underdeveloped countries like Nigeria. Young individuals who receive scientific and technological training can spur innovation, support economic growth, and actively engage in international scientific debates. Accordingly, funding science education is crucial for long-term resilience, sustainable development, and national progress (Jegede, 1999).

Sustainable Development Outcomes

A practical and measurable achievement, sustainable development outcomes in education contribute significantly to the realization of global sustainability objectives, particularly those outlined in the United Nations Sustainable Development Goals (SDGs). These outcomes emphasize expanded access to inclusive and equitable quality education, the attainment of gender parity in school enrolment, and the promotion of lifelong learning opportunities for all. They also integrate global citizenship, human rights, and environmental sustainability into educational curricula and practices. This approach ensures that learners acquire not only academic knowledge but also the critical skills necessary to make positive contributions to their immediate communities and the larger society (Okebukola, 2020).

Because it gives students the information, beliefs, and behaviors they need to make morally sound decisions, education forms the cornerstone of sustainable development. Improved learning environments, more teacher effectiveness, higher literacy rates, and higher school completion rates are all examples of educational achievements that promote sustainability. Furthermore, SDG 4—which highlights the value of high-quality education in enabling people to lead fulfilling lives and tackle global issues—aligns with these results. Students are more likely to behave responsibly as citizens who support social justice, environmental

preservation, and economic equity if they are introduced to sustainability ideals during their early years (Tilbury, 2011).

Along with equity and accessibility, sustainable development outcomes emphasize the value of flexibility, originality, and creativity in the classroom. In the face of environmental challenges and swift technology innovation, educational systems need to adapt to incorporate interdisciplinary learning models, inclusive pedagogy, and digital technologies. With this transformation, pupils are better equipped to handle difficult global issues like poverty, inequality, and climate change. Furthermore, by encouraging critical thinking and problem-solving abilities, education helps create resilient communities that can change societies and economies in the direction of sustainability (Sterling, 2001).

AI-Integrated Science Education

In scientific fields including biology, chemistry, and physics, the deliberate integration of artificial intelligence technology into teaching and learning processes is known as AI-integrated science education. These artificial intelligence (AI) applications include machine learning algorithms that replicate scientific phenomena and offer individualized education, virtual labs, adaptive learning platforms, and intelligent tutoring systems. These resources facilitate personalized instruction by adjusting to the unique learning preferences, speeds, and comprehension levels of each student, creating a more flexible and productive learning environment (Holmes et al., 2019). This technological revolution opens the door to a more student-centered and data-driven educational experience and represents a substantial break from traditional one-size-fits-all teaching approaches. Numerous facets of science education are improved by the incorporation of AI. Students can modify variables in virtual experiments, increasing engagement and helping them better grasp scientific processes. It increases accessibility by giving students in underserved or rural communities access to learning materials, as they might not have access to fully furnished science labs or trained science teachers. Additionally, learners may rectify mistakes in real time and maintain engagement throughout their learning journey thanks to AI capabilities that provide fast feedback on exams and activities. According to Luckin et al. (2016), AI promotes an inclusive learning environment in which all students, regardless of their financial or geographic background, have an equal chance to achieve.

Globally speaking, AI-integrated science education is highly compatible with the Sustainable Development Goals (SDGs) of the UN, especially SDG 4, which calls for universal access to high-quality education and opportunities for lifelong learning. By improving scientific education's accessibility, engagement, and customization to each student's needs, artificial intelligence helps to bridge educational gaps and promote equity. Additionally, by fusing scientific knowledge with computational thinking, AI technologies can foster interdisciplinary learning and hence prepare students for professions in STEM (Science, Technology, Engineering, and Mathematics) disciplines that are essential to sustainability and national innovation (UNESCO, 2021). Critical thinking, creativity, and problem-solving abilities are developed when AI is incorporated into science classes. These abilities are essential for dealing with real-world issues including resource management, public health emergencies, and climate change. Students who possess these abilities not only have better educational experiences but are also better equipped to actively support sustainable community development. When used effectively, AI-driven educational programs foster the development of socially and environmentally conscious individuals in addition to cognitive growth.

Modern educational systems could undergo radical change as a result of AI-integrated science education. In addition to improving the quality and relevance of instruction, it closes access gaps and develops the skills students need to succeed in a technologically advanced, complicated environment. The significance of artificial intelligence (AI) in attaining fair, creative, and sustainable scientific education will grow in importance as governments and educational institutions continue to invest in digital infrastructure and teacher training.

CHALLENGES AND BARRIERS

A number of major obstacles prevent artificial intelligence (AI) from being fully implemented in Nigerian secondary schools, despite the technology's revolutionary promise in science instruction. Lack of proper IT infrastructure is one of the main challenges. Numerous educational institutions nationwide continue to function without reliable access to energy, internet connectivity, or the electronic gadgets required to provide AI-powered teaching resources. Underfunded and remote schools are especially impacted by the digital divide, which restricts pupils' access to contemporary educational tools. Furthermore, there is a severe lack of correctly qualified educators with the technical know-how and digital literacy needed to successfully integrate AI into the classroom. Low adoption rates are a result of the majority of teachers not having gotten formal training on how to integrate AI tools into science classroom.

The meagre funds allotted to public education represent yet another significant barrier. Many organizations cannot afford the enormous expenses of purchasing, adopting, and sustaining AI technologies, particularly in areas with low economic standing. Additionally, some instructors who favour traditional, teacher-centered teaching approaches exhibit significant reluctance to change. Unfamiliarity with AI, concerns about losing one's career, or doubts about the usefulness of automated systems in education can all be the cause of this reluctance. Finally, privacy and ethical issues are brought up by the use of AI in the classroom. Risks relating to data security, consent, and the misuse of personal information may arise from the way AI platforms gather, store, and analyze student data. The widespread implementation of AI in science education throughout Nigeria is still significantly hampered by these worries in the absence of defined legislative frameworks and data privacy rules.

PROSPECTS

There is a lot of promise for incorporating artificial intelligence (AI) into science education in Nigeria, with several chances for growth and change. Increasing access to high-quality science education nationwide, especially in underprivileged and isolated rural regions, is one of the most noteworthy opportunities. Areas that have historically struggled with a lack of competent science teachers and inadequate infrastructure can now receive instructional content thanks to AI-powered digital platforms and mobile learning apps. This can guarantee more fair access to educational opportunities and aid in closing the educational gap between urban and rural areas. AI can offer individualized and flexible learning experiences that are catered to each student's unique requirements and learning style. AI systems can provide tailored instructional content by evaluating learner data to determine strengths, limitations, and preferred learning modes. In scientific classes, this student-centered approach raises comprehension, boosts engagement, and boosts academic achievement. The modernization of the science curriculum has an impact as well. Curriculum designers can update science content to reflect new technologies and practical uses of AI in a variety of scientific domains by integrating AI, which will make learning more current and focused on the future.

Additionally, early exposure to AI principles and resources can support the development of an innovative national culture. Students are more likely to become interested in STEM (science, technology, engineering, and mathematics) occupations if they are exposed to cutting-edge technologies at an early age. This can produce a new generation of creative problem solvers and intellectuals who can support the advancement of the country. Lastly, international cooperation in the field of educational technology can be advantageous for Nigeria. The nation can obtain financial resources, technological know-how, and assistance for the integration of artificial intelligence (AI) into the educational system through collaborations with international organizations, research institutes, and donor agencies. These partnerships have the potential to improve Nigeria's standing in the international digital learning ecosystem, encourage best practices, and hasten the adoption of AI-driven learning technologies.

LONG-TERM IMPACTS ON SCIENCE EDUCATION IN NIGERIA

Long-term educational reform in Nigeria could be greatly aided by the incorporation of artificial intelligence (AI) into science curricula. The possible decrease in educational disparities is among the most important advantages. Regardless of a student's socioeconomic background, geographic location, or access to conventional educational facilities, AI-powered learning systems may provide them with standardized, excellent instructional resources. The difference between urban and rural schools may be lessened as a result. Additionally, by encouraging students' interest in scientific research and experimentation, AI technology can support STEM (Science, Technology, Engineering, and Mathematics) education. Early involvement can result in a workforce that is more creative and skilled, which is essential for Nigeria's socioeconomic growth. Additionally, integrating AI into the classroom is probably going to improve students' and teachers' technology literacy. Students get digital skills necessary to engage in the contemporary digital economy as they work with AI tools. On the other side, teachers learn how to successfully incorporate technology into their lesson plans. The advancement of environmental consciousness via AI-powered simulations, virtual experiments, and real-time data analysis is another significant effect. By assisting students in investigating urgent environmental concerns like pollution and climate change, these resources can foster sustainability thinking and problem-solving abilities. Finally, by guaranteeing inclusive, equitable, and high-quality education while promoting innovation nationwide, the integration of AI into science education supports and aligns with the attainment of Sustainable Development Goals, especially SDG 4 (Quality Education) and SDG 9 (Industry, Innovation, and Infrastructure).

Empirical Review

A comprehensive meta-analysis of the efficacy of AI-based adaptive learning systems in STEM courses was carried out by Holmes et al. (2019). According to their research, post-test results showed that students utilizing AI-powered platforms performed up to 25% better than their counterparts in conventional classrooms. The study specifically emphasized how tailored learning pathways and clever feedback loops built into AI systems have improved student understanding and retention in biology and physics.

Pane et al. (2017) looked into how middle and high school science and math students were affected by personalized learning tools. When compared to pupils in traditional classrooms, the researchers found that students exposed to AI-powered personalized learning tools showed greater levels of engagement and academic improvement. Significantly lower dropout rates were observed as a result of the AI tools' ability to adapt the learning pace to each student's demands, boosting their self-esteem and motivation.

The learning outcomes of students using virtual laboratories were compared to those in traditional labs by Makransky et al. (2020). High school chemistry students participated in a quasi-experimental study, which found that pupils who used AI-powered virtual labs did just as well on tests of conceptual knowledge, if not better. The study underlined that for schools lacking sufficient scientific lab infrastructure, virtual labs provided a scalable, affordable, and secure alternative. Heffernan and Heffernan (2014) investigated how formative assessment tools powered by AI could improve science education. The ASSISTments platform, which offered immediate feedback on student contributions during science exercises, was used in their experimental investigation. According to the findings, pupils who got real-time AI feedback were able to clear up misconceptions more quickly and performed better on follow-up tests than those who did not. A qualitative study involving secondary science instructors utilizing AI tools for classroom instruction was carried out by Luckin et al. (2016). By providing personalized educational materials, automating grading, and using analytics to identify student learning gaps, teachers said AI-supported platforms improved their ability to manage large classrooms. Teachers were able to concentrate more on encouraging students to engage in deeper scientific investigation and conversation thanks to this support.

METHODOLOGY

The study adopted a descriptive research design, the population for the study consisted of 1,899 senior secondary school teachers, drawn from 39 public senior secondary schools in Port Harcourt Metropolis. A purposive sampling technique was employed to select 400 participants with relevant experience and exposure to AI tools. Data were collected through a structured questionnaire designed to capture perceptions of science teachers on AI's contribution to sustainable development, effectiveness in teaching and learning, adoption barriers, and long-term prospects. Mean and standard deviation were used to answer the research questions while t-test was used to test the hypotheses at 0.05 level of significance

RESULTS

Table 1: Mean and Standard Deviation of AI-Integrated Science Education and Sustainable Development Outcomes (RQ1)

| S/N | Questionnaire Item | n | Mean | Std. Deviation | Decision |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|------|----------------|----------|
| 1 | AI-integrated science education enhances students' problem-solving skills in addressing real-world issues related to sustainable development. | 200 | 3.45 | 0.72 | Agree |
| 2 | The use of AI in science classrooms improves students' critical thinking and innovation skills. | 200 | 3.52 | 0.68 | Agree |
| 3 | AI-based tools (e.g., simulations, virtual labs) help students better understand environmental sustainability concepts. | 200 | 3.38 | 0.81 | Agree |
| 4 | AI-integrated teaching methods prepare students to apply scientific knowledge to community development challenges. | 200 | 3.41 | 0.76 | Agree |
| 5 | The integration of AI in science education contributes to achieving Sustainable Development Goals (SDGs) such as quality education, innovation, and climate action. | 200 | 3.49 | 0.70 | Agree |

Grand Mean = 3.45, Std. Dev = 0.73

The findings in Table 1 reveal that teachers largely agreed that AI-integrated science education positively influences sustainable development outcomes in Port Harcourt Metropolis. All five items had mean scores above the neutral benchmark of 3.00, pointing to an overall favorable perception. The highest mean ($M = 3.52$, $SD = 0.68$) was observed for the statement that AI use in science classrooms enhances students' critical thinking and innovation abilities, showing that teachers strongly acknowledge AI's capacity to promote higher-order thinking skills.

In the same vein, the item on AI's contribution to Sustainable Development Goals (SDGs), particularly in areas like quality education, innovation, and climate action, also scored highly ($M = 3.49$, $SD = 0.70$). This outcome reflects the view that AI-based instructional methods are valuable in equipping learners for tackling global and societal challenges. Items such as improving problem-solving skills ($M = 3.45$, $SD = 0.72$) and enabling students to apply scientific knowledge to community development ($M = 3.41$, $SD =$

0.76) further demonstrate that teachers see AI as a bridge between classroom learning and real-world application.

Despite the generally positive results, the lowest mean ($M = 3.38$, $SD = 0.81$) was recorded for the use of AI tools such as simulations and virtual laboratories in understanding environmental sustainability concepts. This indicates that while teachers recognize the usefulness of such tools, their actual application in classrooms may still be limited. In summary, the results highlight that teachers view AI as a strong enabler of education for sustainable development, though practical challenges such as limited access and implementation gaps may still need to be addressed.

Table 2: Mean and Standard Deviation of Challenges and Barriers to AI Adoption in Science Classrooms (RQ2)

| S/N | Questionnaire Item | n | Mean | Std. Deviation | Decision |
|-----|-------------------------------------------------------------------------------------------------------------------------|-----|------|----------------|----------|
| 6 | Inadequate infrastructure (electricity, internet, and digital devices) limits the adoption of AI in science classrooms. | 200 | 3.60 | 0.66 | Agree |
| 7 | Teachers lack adequate training and skills to effectively use AI technologies in science teaching. | 200 | 3.58 | 0.71 | Agree |
| 8 | Students' limited access to personal digital devices restricts the use of AI for learning science. | 200 | 3.42 | 0.75 | Agree |
| 9 | Resistance to change among teachers and students hinders the integration of AI in science education. | 200 | 3.18 | 0.82 | Agree |
| 10 | High cost of acquiring and maintaining AI technologies is a major barrier to their adoption in schools. | 200 | 3.65 | 0.69 | Agree |

The results presented in Table 2 indicate that teachers strongly acknowledge several barriers to the adoption of AI in science classrooms within Port Harcourt Metropolis. All the items had mean values above the neutral point of 3.00, showing overall agreement that these factors present significant challenges. The most prominent barrier was the high cost of acquiring and maintaining AI technologies ($M = 3.65$, $SD = 0.69$), which suggests that financial constraints are a major obstacle to widespread implementation in schools.

Closely following this was the challenge of inadequate infrastructure ($M = 3.60$, $SD = 0.66$), including unreliable electricity supply, poor internet connectivity, and limited access to digital devices. This highlights the fact that without a strong technological foundation, schools may find it difficult to effectively integrate AI into science teaching and learning. Another significant concern was teachers' lack of adequate training and skills to use AI tools effectively ($M = 3.58$, $SD = 0.71$), pointing to the need for professional development and capacity-building initiatives to support educators.

While still agreed upon, the relatively lower mean scores were observed for students' limited access to personal digital devices ($M = 3.42$, $SD = 0.75$) and resistance to change among teachers and students ($M = 3.18$, $SD = 0.82$). These results suggest that although issues of accessibility and attitude remain important, they may be less critical than cost and infrastructure challenges. Overall, the findings emphasize that

structural and financial barriers are the main impediments to AI adoption, and addressing these would be vital for successful integration into science classrooms.

HYPOTHESIS TESTS

Table 3: One-Sample t-test on AI-Integrated Science Education and Sustainable Development Outcomes

| Variable | Test Value (Neutral) | n | Mean | SD | t-value | df | Sig. (p) | Decision |
|---------------------------------------------------------------------------------|----------------------|-----|------|------|---------|-----|----------|-----------------|
| AI-Integrated Science Education contributes to sustainable development outcomes | 3.00 | 200 | 3.45 | 0.72 | 8.85 | 199 | .000 | Reject H_{01} |

The result in Table 3 shows that the mean score ($M = 3.45$, $SD = 0.72$) is significantly higher than the test value of 3.00, $t(199) = 8.85$, $p < .05$. This indicates that teachers perceive AI-integrated science education as making a significant contribution to sustainable development outcomes in Port Harcourt Metropolis. Hence, the null hypothesis (H_{01}) was rejected.

Table 4: One-Sample t-test on Challenges and Barriers to AI Adoption in Science Classrooms

| Variable | Test Value (Neutral) | n | Mean | SD | t-value | df | Sig. (p) | Decision |
|--------------------------------------------------------------------------------|----------------------|-----|------|------|---------|-----|----------|-----------------|
| Challenges and barriers significantly hinder AI adoption in science classrooms | 3.00 | 200 | 3.49 | 0.73 | 9.57 | 199 | .000 | Reject H_{02} |

The result in Table 4 indicates that the mean score ($M = 3.49$, $SD = 0.73$) is significantly higher than the neutral benchmark of 3.00, $t(199) = 9.57$, $p < .05$. This means that teachers strongly perceive challenges such as cost, inadequate infrastructure, and lack of training as significant barriers to AI adoption in science classrooms. Thus, the null hypothesis (H_{02}) was also rejected.

DISCUSSION OF FINDINGS

The findings of this study revealed that teachers in Port Harcourt Metropolis strongly perceive AI-integrated science education as contributing significantly to sustainable development outcomes. With all the items in Section A recording mean scores above the benchmark of 3.00, it is clear that teachers recognize the value of AI in enhancing students' problem-solving, critical thinking, and innovation skills. This finding supports the growing body of literature which emphasizes that AI can transform science education by providing personalized learning opportunities, virtual laboratories, and interactive platforms that foster creativity and real-world application of knowledge (Zawacki-Richter et al., 2019). The result aligns with global evidence that AI enhances learners' competencies for addressing issues related to health, energy, environment, and technology, all of which are central to sustainable development goals.

The study further revealed that teachers agreed that AI-integrated education helps students apply scientific knowledge to community development challenges and contributes directly to achieving Sustainable Development Goals such as quality education, innovation, and climate action. This indicates that AI is perceived not just as a classroom tool but as a driver of broader societal change. Similar to the assertions

of Holmes et al. (2021), AI's role in fostering critical and creative skills makes it an indispensable asset in preparing students for 21st-century challenges. However, the relatively lower mean score for the use of simulations and virtual laboratories suggests that, although teachers recognize the potential of AI, the practical implementation of such tools may still be limited due to infrastructural and resource constraints.

In terms of challenges, the findings in Section B revealed that inadequate infrastructure, lack of teacher training, high costs of acquiring AI technologies, and limited access to digital devices by students remain the most pressing barriers to AI adoption in Port Harcourt science classrooms. These results mirror the observations of Adedokun-Shittu and Shittu (2020), who noted that technology adoption in Nigerian schools is often hindered by poor internet connectivity, unreliable power supply, and limited technical skills. Interestingly, resistance to change among teachers and students, while still significant, recorded the lowest mean score, suggesting that willingness to adopt AI may exist, but systemic constraints such as cost and infrastructure act as greater impediments.

The hypothesis testing further reinforced these results. The rejection of the null hypothesis confirmed that teachers significantly perceive AI-integrated science education as contributing to sustainable development outcomes. Similarly, barriers such as inadequate infrastructure, poor training, and high costs were also significantly perceived as challenges to AI adoption, leading to the rejection of the second null hypothesis. These outcomes imply that while the potential benefits of AI are well recognized, the practical realization of these benefits will require deliberate investment in infrastructure, teacher professional development, and policy frameworks that promote equitable access to AI-driven tools.

The findings demonstrate a dual reality: on one hand, teachers in Port Harcourt Metropolis acknowledge AI's immense potential to drive sustainable education and development; on the other hand, systemic challenges threaten its full integration into classrooms. For AI to realize its transformative promise in the region, policymakers, school administrators, and development partners must prioritize targeted interventions that bridge infrastructural gaps, train teachers in AI application, and reduce the costs of technology acquisition and maintenance. Without these measures, the enthusiasm for AI in education may remain at the level of perception, with limited practical impact on teaching, learning, and sustainable development outcomes.

CONCLUSION

A major paradigm shift in Nigeria's educational system is represented by AI-integrated science education, which offers revolutionary opportunities beyond conventional classroom training. The education system can use personalized learning pathways that are suited to each student's needs, learning preferences, and cognitive capacities by incorporating artificial intelligence into teaching and learning procedures, particularly in science fields. This personalization raises student interest, promotes involvement, and boosts academic achievement in general. Additionally, through data-driven decision-making, intelligent tutoring systems, automated grading, and real-time feedback, AI solutions help instructors make the most of their resources. These features improve the quality of learning while lessening the effort for teachers. Notwithstanding these advantages, there are a number of obstacles to integrating AI into science education in Nigeria, such as poor infrastructure, low teacher digital literacy, expensive implementation costs, and opposition to change. These challenges are not insurmountable, though. The full potential of AI may be achieved with careful strategic planning by educational stakeholders, more funding for technology infrastructure, strong teacher preparation programs, and supporting regulations. Ultimately, by promoting fair access, innovation, and sustainable national growth through science education, the effective integration of AI in science classrooms supports more extensive educational reforms, fits with Nigeria's development agenda, and advances the global Sustainable Development Goals, especially SDG 4 (Quality Education) and SDG 9 (Industry, Innovation, and Infrastructure).

RECOMMENDATIONS

In light of the findings and potential of AI-integrated science education in Nigeria, the following recommendations are proposed to ensure effective implementation, sustainability, and nationwide impact. These strategies are aimed at addressing existing challenges and maximizing the benefits of AI for students, teachers, and the broader educational system:

1. The national curriculum should incorporate AI and digital learning tools in science subjects.
2. Government and stakeholders should invest in digital infrastructure such as devices, internet access, and power supply.
3. Regular professional development programs should be implemented to improve teacher competence in using AI tools.
4. Establishment of ethical guidelines and frameworks for the safe and responsible use of AI in education.
5. Government and stakeholders launch small-scale AI integration projects in selected schools as a foundation for national expansion.

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