

ARTIFICIAL INTELLIGENCE AND SUSTAINABLE DEVELOPMENT SYNERGISING TECHNOLOGY FOR EFFECTIVE PEDAGOGY

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Abstract

The study adopted a descriptive survey research design to ascertain effects accruable to pedagogy as a result of the utilization of Artificial Intelligence driven technology. The population of the study comprised all educational stakeholders who have knowledge of or experience with the use of digital technologies in education in Warri South Local Government Area of Delta State. These include students, teachers/lecturers, and educational administrators. A sample of 200 respondents was selected for the study. The sample comprises 100 students, 80 teachers/lecturers and 20 Educational Administrators giving a total of 200. The sample size of 200 respondents was considered adequate for obtaining a broad representation of the views of the major educational stakeholders. Using a stratified random sampling technique. The respondents were divided into three strata based on their educational roles: students, teachers/lecturers, and educational administrators. The technique was considered appropriate because students, teachers, and administrators have different experiences and responsibilities concerning the adoption and use of Artificial Intelligence in education. Including the three groups therefore provides a more balanced assessment of the research problem. The main instrument for data collection was a structured questionnaire developed by the researcher based on the objectives, research

questions, hypotheses, and relevant literature on Artificial Intelligence and sustainable educational development. The questionnaire was titled “Artificial Intelligence and Sustainable Educational Development Questionnaire (AISEDQ).” The questionnaire consists of two major sections. Section A: Demographic Information and B Section B: Research Items. The questionnaire uses a four-point Likert scale as follows: Strongly Agree (SA) 4; Agree (A) 3; Disagree (D) 2; and Strongly Disagree (SD) 1. The four-point scale was adopted to encourage respondents to indicate a definite position rather than selecting a neutral midpoint. The researcher administered the questionnaires directly to the selected respondents. Before administering the instrument, the researcher explained the purpose of the study to the respondents and obtained their cooperation. The respondents were informed that participation was voluntary and that the information supplied would be used strictly for academic purposes. Adequate time was provided for respondents to complete the questionnaire. Where necessary, the researcher assisted respondents in understanding the instructions without influencing their responses. Completed questionnaires were retrieved, checked for completeness, and prepared for statistical analysis. The data collected were coded and analysed using frequency counts and percentages were used to analyse respondents’ demographic characteristics.

Keywords: Artificial Intelligence, Sustainable Education, Educational Development, Digital, Pedagogy, Innovation, SDG 4.

Introduction

The twenty-first century is witnessing unprecedented technological advancements that continue to reshape virtually every aspect of human life. Among these innovations, Artificial Intelligence has emerged as one of the most transformative technologies, influencing sectors such as

healthcare, agriculture, finance, transportation, governance, and education. Artificial Intelligence refers to computer systems and algorithms capable of performing tasks that traditionally require human intelligence, including learning, reasoning, decision-making, problem-solving, and language processing (Holmes et al., 2022). Nigeria's educational landscape continues to grapple with entrenched systemic barriers that undermine efforts toward achieving equity, operational efficiency, and inclusive digital learning. Despite significant educational policy reforms like Universal Basic Education, Education for All, Home Grown School Feeding, to mention a few, Nigeria still records the highest number of out-of-school children globally, estimated at over 20 million as of 2023 (UNESCO, 2023).

Studies show that more than 70% of Nigerian children cannot read and understand a simple sentence by age 10 which is a stark reflection of persistent learning poverty (World Bank, 2022). These inequities are compounded by structural inefficiencies across the system, ranging from insufficient funding, digital resource gaps decaying infrastructure and poor teacher training to governance deficits (Phillips Consulting, 2022; Okonkwo & Agbatogun, 2023). Many secondary schools still lack basic electricity or internet access, making it nearly impossible to integrate modern learning technologies such as Artificial Intelligence. The national teacher-student ratio remains critically high in the West, South and East, many reaching as much as 1:70 while educational quality suffers due to a lack of culturally relevant instructional materials and limited continuous teacher professional development (Olayemi & Ogunyemi, 2021). In the face of these challenges, Artificial Intelligence has emerged globally as a potentially transformative force in education. The technology promises language translation, personalized learning pathways, real-time feedback, early learner diagnostics and adaptive content delivery (Luckin et al., 2016; Holmes et al., 2019).

In developed countries contexts, Artificial Intelligence powered tools have already been used to reduce administrative burdens, improve student engagement and outcomes and support learners with disabilities. Studies show that Artificial Intelligence tutoring systems can accelerate learning by two or three times compared to traditional methods (World Bank, 2023; Zawacki-Richter et al., 2019). However, Artificial Intelligence integration in Nigeria is just at the developmental stage and uneven (Adewale & Oduwale, 2024); thereby facilitating some private Educational Technology companies like Edves and uLesson leveraging Artificial Intelligence to deliver interactive content to millions of learners. Subsequently, most public education institutions are highly backward in infrastructure provision, technical training and digital culture. According to Adewale & Oduwale (2024) and Olubiyi (2022), this drawback reflects broader systemic dysfunctions such as unclear ethical governance, low teacher readiness, limited national strategies for Artificial Intelligence in education and inadequate indigenous software localization

In education, Artificial Intelligence is increasingly deployed to personalise learning experiences, automate administrative functions, facilitate assessment, and support data-driven decision-making. (Adewale & Oduwale, 2024) Educational institutions across the world are embracing Artificial Intelligence powered tools to improve teaching effectiveness and learning outcomes. According to UNESCO (2024), Artificial Intelligence possesses enormous potential to address educational challenges, foster innovation in teaching and learning, and accelerate progress toward the attainment of Sustainable Development Goal 4 (SDG 4), which focuses on inclusive and equitable quality education for all. The concept of sustainable educational development emphasizes educational systems that are inclusive, equitable, resilient, and capable of meeting present learning needs without compromising future generations' opportunities. Sustainable

educational development therefore requires innovative approaches capable of expanding access to quality education while addressing persistent challenges such as teacher shortages, educational inequalities, inadequate infrastructure, and limited learning resources. The convergence of Artificial Intelligence and sustainable educational development presents significant opportunities. Artificial Intelligence technologies can support adaptive learning, facilitate lifelong learning, improve educational administration, and promote inclusive education for learners with diverse needs. However, the integration of Artificial Intelligence into educational systems also raises critical concerns relating to ethics, privacy, algorithmic bias, digital exclusion, and overdependence on technology. UNESCO (2024) emphasizes that Artificial Intelligence adoption in education must be guided by principles of equity, inclusion, and human-centred development.

According to Adefolu and Ezeani (2023), the discourse on Artificial Intelligence and education in Nigeria reveals several critical research gaps. Study by Adefolu and Ezeani (2023) revealed that there is a marked inadequacy of empirical research on the real-world effectiveness of Artificial Intelligence tools in the Nigerian context. The existing pilot studies such as the World Bank (2023) sponsored revealed the prevalence of Artificial Intelligence enhanced learning in low-income communities; few numbers of peer-reviewed evaluations explore outcomes at scale, particularly for marginalised learners (Adigun & Folorunso, 2023). Adefolu and Ezeani (2023) aver teacher preparedness towards integration and adoption of Artificial Intelligence in facilitating pedagogic experiences seemed critically low. Findings from a study conducted by Okonkwo and Agbatogun (2023) shows that the pre-service teachers report low technological self-efficacy and limited exposure to Artificial Intelligence based instruction. Against this backdrop, this

paper critically examines the synergy between artificial intelligence and sustainable educational development by exploring the opportunities, challenges, and policy implications associated with Artificial Intelligence integration in education.

Theoretical Framework

This study is anchored on the Technological Pedagogical Content Knowledge (TPACK) Framework developed by Mishra and Koehler (2006). The framework emphasizes the integration of technology, pedagogy, and content knowledge in effective teaching and learning. The TPACK framework is particularly relevant to Artificial Intelligence integration because it highlights the need for educators to possess not only subject matter expertise and pedagogical competence but also technological literacy. Successful adoption of Artificial Intelligence technologies in education requires teachers to understand how Artificial Intelligence tools can be integrated into curriculum delivery while maintaining pedagogical effectiveness. The framework suggests that sustainable educational development can only be achieved when technological innovations such as Artificial Intelligence are harmoniously combined with sound pedagogical practices and relevant content knowledge. Therefore, Artificial Intelligence should serve as a complementary tool that enhances teaching and learning rather than replacing educators.

Statement of the Problem

Education remains a fundamental instrument for individual development, social transformation, economic growth, and sustainable national development. However, educational systems continue to face persistent challenges, including inadequate access to quality education, overcrowded classrooms, and shortages of qualified teachers, inadequate instructional resources, poor assessment practices, unequal learning opportunities, and limited technological

infrastructure. These challenges have become more pronounced as educational institutions are increasingly expected to provide flexible, inclusive, learner-centred, and technology-driven education capable of meeting the demands of the twenty-first century. The emergence of Artificial Intelligence (AI) presents new opportunities for addressing some of these challenges. AI-powered educational technologies can support personalized learning, intelligent tutoring, automated assessment, immediate feedback, learning analytics, instructional material development, and educational administration. Consequently, AI is increasingly being regarded as a potentially important instrument for improving educational quality and contributing to Sustainable Development Goal 4, which seeks to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all (UNESCO, 2021, 2023). However, the availability of AI technologies does not automatically translate into sustainable educational development. What could be the cause? Could it be unequal capacity of educational institutions and learners to access and effectively utilize AI technologies, the preparedness of teachers for effective use of AI to achieve appropriate technological, pedagogical, and ethical competencies, or significant ethical and pedagogical concerns? It is against this background that this study investigates the contribution of AI to sustainable educational development.

Purpose of the Study

The purpose of the study is to:

- i. Ascertain the extent Artificial Intelligence contribute to sustainable educational development;
- ii. Determine challenges hindering the effective integration of Artificial Intelligence into education, and
- iii. Identify measures that can promote the sustainable integration of Artificial Intelligence into education.

Research Question

The following research questions guided the study.

- i. To what extent does Artificial Intelligence contribute to sustainable educational development?
- ii. What challenges hinder the effective integration of Artificial Intelligence into education?
- iii. What measures can promote the sustainable integration of Artificial Intelligence into education?

Hypothesis

The study tested the following hypothesis:

H₀₁: There is no significant relationship between Artificial Intelligence adoption and sustainable educational development.

H₀₂: There is no significant relationship between AI-related challenges and sustainable educational development.

H₀₃: There is no significant relationship between the identified measures and sustainable integration of Artificial Intelligence into education.

Methodology

The study adopted a descriptive survey research design to ascertain effects accruable to pedagogy as a result of the utilization of Artificial Intelligence driven technology. The population of the study comprised all educational stakeholders who have knowledge of or experience with the use of digital technologies in education in Warri South Local Government Area of Delta State. These include students, teachers/lecturers, and educational administrators. A sample of 200 respondents was selected for the study. The sample comprises 100 students, 80 teachers/lecturers and 20 Educational Administrators giving a total of 200. The sample size of 200 respondents was considered adequate for obtaining a broad representation of the views of the major educational stakeholders. Using a stratified random sampling technique. The respondents were divided into three strata based on their

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The data collected were coded and analysed using frequency counts and percentages were used to analyse respondents’ demographic characteristics. This provides a clear description of the composition of the sample. The percentage was

calculated using: $\text{Percentage} = (\text{Frequency} / \text{Total Number of Respondents}) \times 100$. The mean was used to determine the level of agreement with each questionnaire item. For the four-point Likert scale, the criterion mean was calculated as: $\text{Criterion Mean} = (4 + 3 + 2 + 1) / 4 = 2.50$. Therefore $\text{Mean} \geq 2.50 = \text{Agree}$ while $\text{Mean} < 2.50 = \text{Disagree}$. The grand mean was also used to determine the overall response to groups of related questionnaire items. Standard deviation was used alongside the mean to determine the degree of variation in respondents' responses. A relatively small standard deviation indicates that responses are clustered around the mean, while a larger standard deviation indicates greater variation among respondents. Pearson Product Moment Correlation Coefficient (PPMC) was used to test the hypotheses concerning the relationships between the major variables. The PPMC was considered appropriate because the study seeks to determine whether statistically significant relationships exist between variables. The hypotheses were tested at the 0.05 level of significance. The decision rule was if $p < 0.05$, reject the null hypothesis and if $p \geq 0.05$, retain the null hypothesis.

Results

Table 1: Distribution of Respondents by Gender

Gender	Frequency	Percentage (%)
Male	112	56.0
Female	88	44.0
Total	200	100.0

Source: Field Survey, 2026

Table 1 shows that 112 respondents (56.0%) were male, while 88 respondents (44.0%) were female. This indicates that both male and female respondents were represented in the study.

Table 2: Distribution of Respondents by Category

Category	Frequency	Percentage (%)
Students	100	50.0
Teachers/Lecturers	80	40.0
Educational Administrators	20	10.0
Total	200	100.0

Source: Field Survey, 2026

The table indicates that students constituted the largest group of respondents with 100 (50.0%), followed by teachers/lecturers with 80 (40.0%), while educational administrators constituted 20 (10.0%).

Research Question One: To what extent can Artificial Intelligence contribute to sustainable educational development?

Table 3: Respondents' Views on the Contribution of AI to Sustainable Educational Development

S/N	Items	SA	A	D	SD	Total
1	AI can improve the quality of teaching and learning.	92	76	20	12	200
2	AI can provide personalized learning experiences.	88	82	18	12	200
3	AI can improve students' access to educational resources.	84	86	20	10	200
4	AI can improve educational assessment and feedback.	90	78	21	11	200
5	AI can improve administrative efficiency in educational institutions.	86	82	20	12	200

Source: Field Survey, 2026

The results show a generally positive perception of AI's contribution to sustainable educational development. For example, 168 respondents (84.0%) either strongly agreed or agreed that AI can improve the quality of teaching and learning. Similarly, 170 respondents (85.0%) agreed that AI can provide personalized learning experiences. Also, 170 respondents (85.0%) agreed that AI can improve access to educational resources. The findings suggest that respondents recognize AI as a potentially important instrument for improving educational quality, accessibility, assessment, and administration. This supports UNESCO (2023), which identifies AI as a technology capable of supporting teaching, learning, assessment, and educational management when appropriately implemented.

Research Question Two: What are the major challenges associated with the integration of AI into education?

Table 4: Respondents’ Views on Challenges of AI Integration

S/N	Items	SA	A	D	SD	Total
1	Poor internet connectivity limits the effective use of AI in education.	104	70	16	10	200
2	Inadequate digital infrastructure is a major barrier to AI adoption.	108	68	15	9	200
3	Lack of teacher training limits effective AI integration.	96	78	17	9	200
4	Data privacy is a major concern in the use of AI in education.	91	82	18	9	200
5	The digital divide may increase educational inequality.	98	76	17	9	200

Source: Field Survey, 2026

Table 4 reveals that respondents identified several challenges associated with AI adoption. A total of 174 respondents (87.0%) agreed that poor internet connectivity limits effective AI use. Similarly, 176 respondents (88.0%) agreed that inadequate digital infrastructure constitutes a major barrier. Furthermore, 174 respondents (87.0%) agreed that inadequate teacher training limits effective AI integration. Data privacy was also considered important, with 173 respondents (86.5%) agreeing that it constitutes a major concern. The findings demonstrate that technological and human capacity remain critical requirements for sustainable AI adoption for pedagogical excellence. These findings are consistent with UNESCO (2023), which emphasizes that AI adoption must address issues relating to equity, privacy, inclusion, human capacity, and responsible use.

Research Question Three: What measures can promote the sustainable integration of AI in education?

Table 5: Respondents' Views on Measures for Sustainable AI Integration

S/N	Items	SA	A	D	SD	Total
1	Government should improve digital infrastructure in schools.	110	70	12	8	200
2	Teachers should receive regular AI training.	106	76	11	7	200
3	Schools should develop clear policies on responsible AI use.	101	82	10	7	200
4	Data protection measures should be strengthened.	104	78	11	7	200
5	AI should complement rather than replace teachers.	116	68	10	6	200

Source: Field Survey, 2026

Table 5 shows strong support for measures aimed at promoting sustainable AI integration. A total of 180 respondents (90.0%) agreed that government should improve digital infrastructure. Similarly, 182 respondents (91.0%) supported regular AI training for teachers. The highest level of agreement was recorded for the view that AI should complement rather than replace teachers, with 184 respondents (92.0%) agreeing. This finding emphasizes the continuing importance of human teachers in educational development. The result supports the human-centred approach advocated by UNESCO (2021, 2023), which stresses that technological innovation should strengthen human capabilities and promote equitable educational development.

Test of Hypotheses

Hypothesis One: There is no significant relationship between Artificial Intelligence adoption and sustainable educational development.

Table 6: PPMC Analysis of the Relationship between AI Use and Teaching/Learning Effectiveness

Variables	N	Mean	SD	r	p-value	Decision
AI Use	200	3.24	0.61			
Teaching/Learning Effectiveness	200	3.26	0.59	0.71	< .001	Significant

Source: Computed from respondents' responses, 2026

Table 6 shows a correlation coefficient of $r = 0.71$ and a p-value of less than .001. Since the p-value is less than the 0.05 level of significance, the null hypothesis is rejected. Therefore, there is a significant positive relationship between the use of Artificial Intelligence and teaching and learning effectiveness. The correlation coefficient of 0.71 indicates a strong positive relationship, suggesting that increased use of AI is associated with improved teaching and learning effectiveness.

Hypothesis two: There is no significant relationship between AI-related challenges and sustainable educational development.

Table 7: PPMC Analysis of the Relationship between AI-Related Challenges and Sustainable Educational Development

Variables	N	Mean	SD	r	p-value	Decision
AI-Related Challenges	200	3.33	0.58			
Sustainable Educational Development	200	3.31	0.58	-0.62	< .001	Significant

Source: Computed from respondents' responses, 2026

Table 7 shows a correlation coefficient of $r = -0.62$ and a p-value of less than .001. Since the p-value is less than 0.05, the null hypothesis is rejected. The result indicates a significant negative relationship between AI-related challenges and sustainable educational development. The negative correlation means that as challenges such as inadequate infrastructure, poor internet connectivity, insufficient teacher training, privacy concerns, and the digital divide increase, the perceived contribution of AI to sustainable educational development tends to decrease.

Hypothesis Three: There is no significant relationship between the identified measures and the sustainable integration of Artificial Intelligence into education.

Table 8: PPMC Analysis of the Relationship between Identified Measures and Sustainable Integration of AI into Education

Variables	N	Mean	SD	r	p-value	Decision
Identified Measures	200	3.42	0.55			
Sustainable AI Integration	200	3.36	0.57	0.78	< .001	Significant

Source: Computed from respondents' responses, 2026.

Table 8 shows that the Pearson Product Moment Correlation Coefficient between the identified measures and sustainable integration of Artificial Intelligence into education is $r = 0.78$, with a p-value of less than .001. Since the p-value (.001) is less than the 0.05 level of significance, the null hypothesis is rejected. Therefore, there is a significant positive relationship between the identified measures and sustainable integration of Artificial Intelligence into education.

The correlation coefficient of 0.78 indicates a strong positive relationship. This implies that improvement in measures such as digital infrastructure, teacher training, data protection, responsible AI policies, equitable access, adequate funding, and continuous monitoring is associated with greater sustainable integration of AI into education. The finding suggests that the successful adoption of AI cannot depend solely on the availability of AI technologies. Rather, sustainable integration requires an enabling educational environment in which teachers are adequately prepared, infrastructure is available, ethical standards are established, and learners have equitable access to AI-supported educational resources.

Discussion of Findings

The results of the hypothesis testing demonstrate that Artificial Intelligence has a statistically significant relationship

with several dimensions of sustainable educational development. The first hypothesis established a strong positive relationship between AI adoption and sustainable educational development ($r = 0.74$). This suggests that increased adoption of AI is associated with improved perceptions of educational sustainability. The second hypothesis also revealed a coefficient of $r = -0.62$ and a p-value of less than .001. Since the p-value is less than 0.05, the null hypothesis is rejected. The result indicates a significant negative relationship between AI-related challenges and sustainable educational development. The negative correlation means that as challenges such as inadequate infrastructure, poor internet connectivity, insufficient teacher training, privacy concerns, and the digital divide increase, the perceived contribution of AI to sustainable educational development tends to decrease.. The third hypothesis produced a positive correlation of 0.78 between AI-supported educational practices and inclusive and equitable education. This suggests that AI can potentially support learners with diverse educational needs. However, equitable access to the technology remains essential because unequal access could reproduce existing educational inequalities. Taken together, the results demonstrate that AI has substantial potential to support sustainable educational development, but the realization of this potential depends on effective implementation, teacher competence, adequate infrastructure, equitable access, and responsible governance.

Conclusion

Findings of the study show AI contributes positively to sustainable educational development, AI improves teaching and learning effectiveness, though infrastructure and technological limitations constitute major barriers, AI can promote inclusive and equitable education. By aligning technological innovation with inclusive policies, systemic reforms, and collaborative research-practice-policy cycles, Nigeria can harness Artificial Intelligence to improve learning

outcomes, reduce inequality, and modernize its education system for the future. In summary, Artificial Intelligence holds the potential to transform Nigeria's education sector, but its success depends on how well foundational gaps are addressed, contents are localised; teachers are empowered, and governance is ethically aligned. Rescinding Nigeria's entrenched educational challenges requires a paradigmatic shift, where Artificial Intelligence is not just a technological novelty but a strategic, inclusive, and ethical tool for system-wide transformation. Therefore, addressing enabling teacher readiness, infrastructure deficits, promoting inclusive design, and embedding strong ethical and data governance frameworks will in no small measure unlocks Artificial Intelligence's full potential of technological engagement in Nigeria. Subsequently, progress will be birth via sustained investment, political will and evidence-based policy implementation that respects Nigeria's unique socio-cultural fabric and educational disparities. With coordinated multi-stakeholder engagement, context-aware infrastructure, inclusive policies, and sustained research, Nigeria can move beyond fragmented interventions toward a resilient, Artificial Intelligence enhanced educational future.

Recommendations

The following recommendations are made:

1. Government, non-governmental organizations and educational stakeholders should encourage prioritising the provision of foundational infrastructural facilities (internet connectivity, rural electrification, and access to emerging technological devices) as prerequisites for sustainable Artificial Intelligence integration.
2. Educational stakeholders should encourage establishment of unified roadmap that emphasizes teacher capacity development, ethical governance, use of localised content, and inclusivity irrespective of individual special need.

3. Educational stakeholders (curriculum planners, developers and implementers) should encourage the development of indigenous Artificial Intelligence powered educational applications that are aligned with Nigeria's curriculum, diverse languages, and multi-cultural contexts.
4. Educational stakeholders, Government and non-governmental organisations should institutionalize continuous Artificial Intelligence-focused professional development and that would support embedding digital pedagogy into pre-service teacher training for professional development.
5. Government and non-governmental organisations should encourage the deployment and engagement of Artificial Intelligence systems that will address disability inclusion, gender equity and support indigent students in rural and conflict-affected areas.

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