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Artificial Intelligence, Teacher Competence, and Students' Learning Outcomes in Science Education: A Multilevel Analysis

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Abstract

Technology, specifically Artificial Intelligence (AI), has emerged as a contender to revolutionize the effectiveness of teaching practice and the learning outcomes of students, in the context of education science. In science education, the rise of Artificial Intelligence (AI) has presented a new horizon of potential enhancements to teaching effectiveness and student learning outcomes. Yet, AI's learning potential will be dependent on a significant extent on teachers' ability to incorporate it into classroom activities. This study aimed to discuss the impact of using AI and teacher competence on students' learning achievements in science education in terms of its multilevel analytical framework. The survey design used was a multilevel correlational survey design. 330 respondents including 30 science teachers and 300 senior secondary school science students were recruited using multistage sampling technique from six public secondary schools in Bwari Area Council FCT Abuja Nigeria. Artificial Intelligence Integration and Teacher Competence Questionnaire (AITCQ) were used to gather data, along with the Student Learning Questionnaire (SLQ) and Science Achievement Test (SAT). Data was analyzed using descriptive statistics and Hierarchical Linear Modelling (HLM) at 0.05 level of significance. The results showed that there was a clear significant impact in the learning outcomes of the students when using the use of artificial intelligence while teacher competence was the top predictor in science achievement. The AI integration-Learning outcomes association was also positively moderated by school ICT infrastructure. The researchers have agreed that it is a synergistic effect of well-trained educators, suitable technology, and positive institutional policies to achieve effective learning use of AI in science education. It endorses the continued investment in teachers' AI upskilling, enhanced digital infrastructure and curriculum changes that incorporate the need for AI skills into teacher education

programs. The study adds to the on-going body of research related to AI and education by showcasing how effectively AI can augment instructional capacity with science teachers.

Keywords: Artificial Intelligence; Teacher Competence; Science Education; Students' Learning Outcomes; Multilevel Analysis

Introduction

Recently, Artificial Intelligence (AI) has become one of the most transformative technologies impacting worldwide education systems. Thanks to the progress of machine learning, natural language processing, Intelligent Tutoring Systems, Learning Analytics and Generative AI these areas of teaching, learning and assessment have become transformed. AI is not about replacing teachers, but about delivering personalised learning, adaptive assessment, feedback, and evidence-based decision making to improve teaching and learning. Miao and Cukurova (2024) identified these opportunities, and introduced the AI Competency Framework for Teachers that centres on the need for teachers to acquire new competencies to ensure human-centred education in an ethical, responsible and effective way when facing challenges of classroom practice involving AI. The use of AI has brought in unique innovations like the ability to assist in visualization and simulation, which are areas where science education has seen significant advances due to the need for experimentation, inquiry, modelling, and problem-solving in scientific inquiry. They all offer students chances to see complex scientific concepts, to virtually conduct experiments, to get feedback and to experience personalised learning in a virtual laboratory, in an intelligent tutoring system, through simulations, or using generative AI applications. These technologies can enhance the conceptual understanding, the scientific thought process and interactions in class, and can diminish the constraints of lack of access to laboratories and teaching materials, particularly in developing countries. The studies involve AI-integrated learning environments, and their findings suggest a positive correlation between AI usage and learning outcomes within a specific pedagogical context.The studies discussed suggest that, overall, the learning outcomes in AI-assisted instructional environments are better when the latter are used within specific pedagogical contexts. The rapid rise of generative AI platforms such as ChatGPT, Google Gemini, Microsoft Copilot, and Claude has enhanced opportunities to innovate teaching and learning. The apps empower teachers for lesson planning, content creation, assessment design, differentiated instruction, and providing feedback, while personalizing learning and providing interactive tutoring and collaborative learning experiences for students Fadipe etal 2024. Educational researchers, however, warn that generative AI's impact on educational results is as much about how educators utilize the technologies as it is about the technologies themselves. For maximum benefit, AI should be used alongside good pedagogy, and to further promoted the use of higher-order thinking, and to further encourage inquiry-based learning rather than to replace students' thinking.

The critical role of the teacher in successful integration of AI-based technology still cannot be overlooked, and teaching excellence will undoubtedly continue to play a pivotal role in this process. Modern definitions of teacher competence go far beyond knowledge of the subject matter, and include technological knowledge, pedagogical skills, digital literacy,

ethical proceedings, and creating meaningful learning experiences with the aid of AI. In teaching, teachers need to take up the role of designing learning systems with the help of AI, supporting learners' inquiry, and being responsible for the ethical use of AI in the educational situation, according to Miao and Cukurova (2024). Educators with such skills are better suited to utilize AI effectively, engage students and enhance learning outcomes. Although a lot of resource has been invested in digital education teaching, according to the study by Peter and Fadipe (2025) and Fadipe (2025), many secondary schools in Nigeria are still facing some impediments in science education such as the inadequate technology infrastructure, long lack of digital educational resources, poor teachers training, and relatively low student performance in science. While AI technologies hold promise of solutions to some of these issues, educational outcomes of AI technologies are contingent upon institutional preparedness, school environment, and teachers' capabilities. Combining AI integration and teacher competence into determining students learning outcomes has drawn attention of educational policymakers and practitioners as an important research topic. Research from the past shows positive interactions of learning and AI but it also poses a few questions. First, numerous existing studies have examined teachers' perceptions and/or acceptance or readiness to implement AI but not its impact on students' learning outcomes. Secondly, AI tools are sometimes studied in isolation, even though their impact is fundamentally interconnected with teacher competence. Secondly, the impact of AI tools and teacher competence are studied separately, although there are strong indications that there is interdependency. Third, few studies have used mutli-level analytical methods that can differentiate the impact at the student level, teacher level, and school level on students' academic achievement. Finally, empirical studies related to Science education in Nigeria secondary schools are still limited, and more studies on a similar nature which is context specific and oriented to inform policy and educational practice are still needed.

This study aims to fill this gap by exploring the impact of the integration of AI and teachers' competence on science education learning outcomes through a multilevel analysis framework. The study's findings unravel the complex dynamics of supporting students in learning science in AI-supported learning by examining student-, teacher-, and school-level factors together. The results will be used to inform educational policy, teacher training, and institutional approaches to effective use of AI in science education.

Objectives of the Study

The study sought to:

1. examine the influence of artificial intelligence integration on students' learning outcomes in science education;
2. determine the influence of teacher competence on students' learning outcomes in science education;
3. investigate the joint influence of artificial intelligence integration and teacher competence on students' learning outcomes in science education; and
4. determine whether school ICT infrastructure moderates the relationship between artificial intelligence integration and students' learning outcomes in science education.

Research Questions

The following research questions guided the study:

1. To what extent does artificial intelligence integration influence students' learning outcomes in science education?

2. What is the influence of teacher competence on students' learning outcomes in science education?
3. What is the joint influence of artificial intelligence integration and teacher competence on students' learning outcomes in science education?
4. Does school ICT infrastructure moderate the relationship between artificial intelligence integration and students' learning outcomes in science education?

Research Hypotheses

The following null hypotheses were tested at the 0.05 level of significance:

H01: Artificial intelligence integration has no significant influence on students' learning outcomes in science education.

H02: Teacher competence has no significant influence on students' learning outcomes in science education.

H03: Artificial intelligence integration and teacher competence do not jointly have a significant influence on students' learning outcomes in science education.

H04: School ICT infrastructure does not significantly moderate the relationship between artificial intelligence integration and students' learning outcomes in science education.

Artificial Intelligence, Teacher Competence and Students' Learning Outcomes

AI is a significant enabler of learning innovation with personalised learning, intelligent tutoring, automated assessment, learning analytics, and adaptive instructional support. Unlike previous educational technologies, modern AI systems can create lesson materials, instantaneously deliver feedback, assist in designing lessons, and facilitate collaborative learning – among other abilities with the help of generative AI tools like ChatGPT, Google Gemini, Microsoft Copilot and Claude. The potential of AI to enhance teaching practices and student learning outcomes in various educational settings has sparked interest. International organizations, however, call for AI being used as a complement to, and not a substitute for, the teacher, and that AI be used in pedagogically appropriate and ethical contexts that foster an environment of inclusion. In science education, AI presents distinct opportunities, as one of the four key pillars of scientific learning – experimentation, investigation, modelling, and problem solving – is very much centred on experimentation and investigation. AI tools and simulations, virtual labs, adaptive learning, and intelligent tutoring platforms allow students to explore abstract concepts, perform experiments in limited-resource settings, and get formative feedback in real-time. The features which they contain support conceptual understanding, scientific reasoning and pupils' engagement as well as increasing access to hands-on scientific experiences. However, the learning outcomes of AI do not only rely on whether teachers use the technology or not but to how well they do this in their lessons. K-12 studies also show that, with proper design of instructional content and methods, AI education can be used to promote AI literacy, problem-solving skills, motivating behaviors, and ethical considerations (Ng et al., 2024). This is aligned with a larger discussion of AI in education to support and complement — but never replace — teachers and human decisions in the classroom (Holmes et al., 2019).

This nuanced take on AI technologies is further reinforced by the broader field of generative-AI literature. Research and practice have also been identified as areas with significant opportunities and challenges for generative conversational AI by Dwivedi et al. (2023), and its use for educational support and concerns around its accuracy, bias, privacy, and over-reliance were also noted by Kasneci et al.

(2023). These factors hold greater weight in science education, where students must assess the evidence, conduct and formulate their own reasoning, rather than copy and paste AI-provided solutions.

But teacher competence is certainly still a key factor in successful AI integration. Modern teacher skills include content knowledge, pedagogical knowledge, technological skills, AI literacy, ethical awareness, and the ability to design activities focusing on learning. With the advent of AI, teachers have shifted from the roles of knowledge transmitters to that of learning designers, facilitators and evaluators who can use intelligent systems in the teaching and learning process. Research in recent times suggests that the teachers with higher technological pedagogical content knowledge (TPACK) to use AI are more likely to use this technology effectively and design learning contexts that foster student motivation and achievement in learning. The overall consensus from empirical evidence indicates a positive impact of AI in education, with the effects being context-dependent. Evidence from systematic reviews demonstrates that the use of AI can improve personalised learning, formative assessment of students' learning, and student engagement, provided it is implemented with a suitable pedagogy and institutional support.Systematic reviews indicate that AI can improve several aspects of personalised learning, formative assessment of students' learning, and engagement when used with suitable pedagogy and institutional support. Several studies, however, have also raised problems of dependency on AI, decreased critical thinking, ethics, or data privacy, algorithmic bias, or inequalities in access to technology. This research indicates that positive educational outcomes are not just a result of the presence of the AI, but the interplay between the technology, teachers' skills, and the school context and culture. While the study area of AI in education has grown significantly, the following three areas of great need have developed. The first is that they often focus on teachers' perceptions, readiness or acceptance of AI instead of the impact on measurable student learning outcomes. Third, the focus is on the technical aspects of instructional technology without exploring how they influence the effectiveness of digital tools.Third, there is a gap between the examination of AI integration and teacher competence, while they complement each other in technology-enhanced instruction. Third, few studies, especially in sub-Saharan Africa, use multilevel analysis approaches to identify the contribution of student, teacher, and school level to academic achievement. Addressing these gaps is essential especially for Nigeria, where the use of AI in secondary schools is becoming an emerging issue in tandem with ongoing problems of ICT facilities, quality teacher preparation in science and the performance of students in science. These limitations are overcome in this study, which leverages a multilevel analytical framework that examines the synergy between the impact of the integration of AI and the competences of teachers on students' learning outcomes. This unease reflects earlier findings in higher education that there is sometimes more focus on how technology can be applied than what the educator's field of study or vantage point of the technology might be (Zawacki-Richter et al., 2019).

Theoretical Framework

The study provides a foundation upon the model of Technological Pedagogical Content Knowledge (TPACK) (Mishra & Koehler, 2006) and reinforced by the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003).

TPACK theory states that integrating technology in ways that are effective is achieved when an educator is able to successfully bring together their technological, pedagogical and content knowledge to help improve learning. Teachers must also be proficient not just in science content but also in how to choose, modify, and assess AI tools for teaching and learning that are aligned to science content and learning needs. Therefore, TPACK offers a suitable explanation for the educational effectiveness of AI based on the teachers' competence levels. The framework is particularly appropriate for science education in the

age of Artificial Intelligence (AI), supported by relevant technology, in which teachers need to plan the technological affordances, the science content, and the pedagogical purposes of AI artifacts (Mishra and Koehler, 2006; Almasri, 2024).

The Utah model of Technological Pedagogical and Content knowledge (UTAUT) complements and explains technology adoption from a behavioural and an organizational perspective. The technology acceptance is based on the four determinants of UTAUT which are: performance expectancy, effort expectancy, social influence, and facilitating conditions. Facilitating conditions in schools encompass ICT infrastructure, institutional support, teacher professional development, and organisational readiness—all of which impact teachers' readiness and willingness to incorporate AI into their teaching. The studies on AI in education over the past few years have once again confirmed that TPACK + UTAUT is a good fitting explanation model for teacher's AI competence and AI technology use. The integration of AI with science pedagogy, teacher capacity to implement the technology, and the school's context all interact in shaping the students' learning outcomes; together, TPACK and UTAUT provide an extensive theoretical framework to understand these interactions. Teachers' dispositions and capabilities to use AI tools are especially highlighted in the current context of performance expectancy, facilitating conditions, and institutional support (Venkatesh et al. 2003; Bali et al. 2024).

Research Design

In this study, the design used was a multilevel correlational survey design, where they examined the effect of Artificial Intelligence (AI) integration and teacher competence on students' learning outcomes in the field of science education. This design was found suitable since it wanted to find out the relationship between variables without changing the variables. Since the education set was hierarchical (students in each schools), the information was analyzed using a multilevel approach to include individual- and school-level effects.

Study Area

The study was done in the Bwari Area Council, Federal Capital Territory (FCT), Abuja, Nigeria. The Area Council has urban and peri-urban public secondary schools with the gradual integration of Digital Technologies in their teaching and learning. This context allowed the exploration of the issues of science education and integration with AI in this environment while preserving teacher competence.

Population

The population for this study included 5,380 senior secondary school science students and 475 science teachers from public secondary schools of Bwari Area Council in the population of 5,855.

Sample and Sampling Technique

There was a multistaging sampling technique. Sixty public secondary schools were selected by simple random sampling (SRS) as the first schools. Then, science teachers from the participating schools were proportionately selected and senior secondary science students were also proportionately selected. The final sample was 330 respondents, 30 science teachers and 300 science students.

Various tools are needed for data collection.Various data collection devices are required.

Three instruments were used for data collection:

1. AI Integration and Teacher Competence Questionnaire (AITCQ): This questionnaire was developed to assess the teacher's AI integration practices, technological competence, pedagogical competence, AI readiness and demographic features by Likert scale from 1 to 5.

2. Student Learning Questionnaire (SLQ): This tool was used to measure students' motivation and engagement along with their perceptions of learning with AI in science.
3. Science Achievement Test (SAT): An achievement test multiple choice type items developed from researcher's point of view based on the senior secondary science curriculum was used to measure the academic performance of students.

Validity and Reliability

The research instruments were face and content validated by science education experts, educational technology experts and measurement and evaluation experts. Confirmatory Factor Analysis (CFA) was also used to explore the construct validity. The internal consistency reliability was evaluated by Cronbach's alpha coefficients, Composite Reliability (CR), and Average Variance Extracted (AVE). The reliability (Cronbach's $\alpha \geq .70$) and convergent validity ($CR \geq .70$; $AVE \geq .50$) of all constructs were acceptable.

Data Collection Procedure

All the necessary educational authorities were obtained ethics approval prior to data collection. The principals of the schools were then contacted for permission. Everyone participated voluntarily and informed consent was obtained. The questionnaires and achievement test were given during regular school hours with the use of trained research assistants. Instruments completed were checked for completeness before coding and analysis.

Data Analysis

Data were analysed using descriptive and inferential statistics. The characteristics of the respondents and the study variables were summarised by descriptive statistics, such as frequencies, percentages, means and standard deviations. For the purpose of investigating the influence of student- and teacher-level, and school-level variables on students' learning outcomes, while keeping the nested structure of the data in mind, Hierarchical Linear Modelling (HLM) was used. The differences were considered statistically significant at the 0.05 significance level.

Results

The 300 SS students and 30 science teachers participated in the study making a total of 330, who represented the schools from the six public secondary schools in Bwari Area Council, Abuja. Of the teachers, 56.7% of whom were male and 43.3% of whom were female. The majority of teachers had a science education bachelor's degree with an average of 11.8 years teaching experience. A total of 52.0% of the students were male and 48.0% were female, between 15-18 years old.

Table1: Descriptive Statistics and Reliability of the Study Variables (N = 330)

Variable	Mean	SD	Cronbach's α
AI Integration	3.71	0.68	.89
Teacher Competence	3.83	0.64	.91
Student Motivation	3.76	0.66	.87
Student Engagement	3.61	0.71	85
Science Achievement	67.84	10.52	82

The descriptive statistics showed a relatively high level of integration of AI and science teacher competence. Students were also found to have high degrees of achievement and engagement in the subject of science with the average achievement score for the subject being of 'moderate' achievement. All study variables had satisfactory internal consistency (Cronbach alpha ranged from .82 to .91).

Table 2: Pearson Correlation Matrix

Variable	1	2	3	4	5
1. AI Integration	1.00				
2. Teacher Competence	.58**	1.00			
3. Student Motivation	.47**	.51**	1.00		
4. Student Engagement	.39**	.43**	.62**	1.00	
5. Science Achievement	.41**	.48**	.45**	.36**	1.00

Note. p < .01.

The correlation analysis showed that the values of major study variables were significantly and positively correlated with one another. Among teacher competence and student's achievement in science, the most strongly correlated was the former ($r = .48$, $p < .01$) with the latter, while the second was also correlation with the r of .41 ($p < .01$). This implies that as teachers become more competent and actively engage in integrating AI, student learning outcomes are linked with better performance.

Table 3: **Hierarchical Linear Model Predicting Students' Science Achievement**

Predictor	Estimate (γ)	SE	t	P
Intercept	45.28	5.03	9.00	< .001
Student Motivation	3.35	0.88	3.81	< .001
Student Engagement	1.96	0.82	2.39	.017
AI Integration	4.12	1.28	3.22	.002
Teacher Competence	5.43	1.36	3.99	< .001
School ICT Infrastructure	2.84	1.09	2.61	.010
AI Readiness	1.08	1.02	1.06	.291

Model Statistics: $R^2 = .31$; Deviance = 35.81; $p < .001$.

Multilevel analysis revealed that teacher competence was the next most significant factor influencing students' science achievement ($\gamma = 5.43$, $p < .001$), while AI integration ($\gamma = 4.12$, $p = .002$) was also significant. A motivation and engagement of students was another significant influence on student achievement relating to science. School information and communication technology (ICT) infrastructure showed a high and significant positive relationship with students' learning outcomes, while no statistically significant relationship was observed between AI readiness and the students' learning outcomes after adjusting the other variables.

Table 4: Hypothesis Testing

Hypothesis	Decision
H01: AI integration has no significant influence on students' learning outcomes.	Rejected
H02: Teacher competence has no significant influence on students' learning outcomes.	Rejected

Hypothesis	Decision
H03: AI integration and teacher competence do not jointly influence students' learning outcomes.	Rejected
H04: School ICT infrastructure does not moderate the relationship between AI integration and students' learning outcomes.	Rejected

The results of this study show that proper implementation of AI and teacher competence plays a significant role in improving students' learning achievements in science learning. ICTs reinforces these connections, though teacher competency will be the most significant factor influencing the pedagogical value of the use of AI in teaching.

Discussion

The effect of the role of Artificial Intelligence (AI) implementation and teacher competency on the students' learning outcomes in science education has been analyzed on two levels namely learners and teachers. The results show the importance of both the integration of AI at the school and the competence of the teacher, as both factors have a significant impact on students' academic performance, and also in the usage of school's ICT infrastructure as a contextual support for the correct implementation of AI.

The first relevant discovery was that the incorporation of artificial intelligence into science education has a significant prediction for student learning outcomes.The first major discovery was that the use of artificial intelligence has a significant prediction for student learning outcomes in science education. This discovery indicates that improved use of AI-supported teaching tools positively impacts students' interest, engagement and academic performance. The opportunities presented by AI technologies in teaching and learning are those of personalized teaching, adaptive feedback, intelligent tutoring and virtual experiments which are conducive to active learning and development of conceptual understanding. This result aligns with the recent systematic reviews, which assert that the use of AI in the learning environment mostly has a positive effect on students' learning outcomes when it is being used in a proper pedagogical manner (Almasri, 2024; Ogunleye et al., 2024; Yusuf et al., 2024). Additionally, it echoes UNESCO's stance of using AI to enhance the teaching and learning processes, not to eliminate the role of the teacher.

The research also revealed that teacher competence was most important in determining the results of students' learning. In short, the findings lend support to the point that knowledge of educational technology in and of itself is not enough for better learning and it is the skill of the teacher in using technology in the class that make it effective in learning. Affective pedagogical knowledge, technoliteracy, and AI literacy enable teachers to create engaging learning tasks, yield appropriate guidance for teaching and learning, and promote inquiry-based learning in a science classroom. This result is parallel with Technological Pedagogical Content Knowledge (TPACK) (Mishra & Koehler, 2006) which indicates that the effective integration of technology requires an interaction of three types of knowledge – Technological Knowledge, Pedagogical Knowledge, and Content Knowledge. AI experts have additionally discovered that educators' knowledge of AI is also a determining factor in students' engagement and results in technology-enhanced learning settings (Tenberga & Daniela, 2024; Ayanwale et al., 2024; Sperling et al., 2024).

Another crucial discovery was that skill enhancement in AI and teacher competence significantly explained the variance in students' science achievement. This shows that using AI and teacher skills is not an exclusive approach to instruction but one that is integrated into effective pedagogy. AI offers

intelligent support for instruction, while capable educators make decisions about how technology is used in how curriculum is delivered, assessed, and used in class. This is also found to be consistent with Unified Theory of Acceptance and Use of Technology (UTAUT) as proposed by Venkatesh et al. (2003) states that technology adoption depends on users' competency along with facilitating conditions.

Another significant finding of the study is the modest yet influential role of school ICT infrastructure between the link between AI integration and students' learning outcomes. It signifies that classrooms with higher tech infrastructure are getting more learning value from the support of AI in teaching than those who lack extensive tech resources. However, the impact of technological infrastructure is relatively small, suggesting that by itself, technological infrastructure cannot ensure more effective learning. Teachers need pedagogically appropriate practices, consistent leadership and professional development to effectively implement AI. This is in line with the latest global evidence, which shows that the effects of AI on education are best realized when technological skills and infrastructure are combined with teachers' competence and institutional support (Bali et al., 2024; UNESCO, 2024).

The overall results underscore the systemic approach in implementing AI in science education. To pair these investments with frameworks that enable continued professional development for teachers, emphasizing AI literacy, technological pedagogical skills, and ethical usage of AI. An integrated approach will have a better chance of enhancing the quality of science teaching, student learning and sustainable innovation of science teaching in Nigerian secondary schools.

Conclusion

The study problem was to find out how the integration of artificial intelligence (AI) and how the teacher does science education affects scientific learning outcomes, both in the form of effect and interaction. Both concepts investigated in this study are used in science education.The influence of the use of artificial intelligence (AI) integration and teacher competence on the achievement of scientific learning outcomes as an interaction effect was investigated in this study. Both concepts included in the object of this study are relevant in science education. Overall, the results reveal that the implementation of AI has a positive impact on students' learning outcomes, provided that teachers are knowledgeable and willing to adopt AI tools, and schools create enabling environments. However, Teacher competence proved to be the most salient factor affecting students' science achievement, suggesting the importance of teachers in the process of making technological innovations effective in the educational domain. Additionally, school infrastructure positively contributed to students' learning outcomes, when AI was integrated, yet the effectiveness of this amplification was dependent upon teachers' correct use of the available technologies. The study builds new content on the expanding body of work on the use of AI in education and shows that this successful implementation needs interplay between the technological, pedagogical and organisational aspects and not only the adoption of the technology. The results also empirically validate TPACK and UTAUT as important frameworks, revealing that for successful use of AI in science teaching, teacher capabilities and facilitating conditions are crucial.

Recommendations

More rigorous and systematic research design, such as longitudinal and/or experimental studies, should be utilized in future research to examine the longer-term impacts of AI-supported teaching on student learning outcomes and their higher-order thinking skills. Contextual influences on the realization of AI on all geopolitical zones of Nigeria could be the hypotheses proved if there is comparative study between public and private schools in various geopolitical zones of Nigeria. Also, other intervening and moderating factors such as teacher's Self-efficacy with AI, Digital leadership of the teacher,

Organisational culture of the school, characteristics of learners, and ethical issues on the use of generative AI in schools should be explored to deepen the study. The studies could help further the understanding of how sustainable AI can be incorporated into science instruction.

References

Almasri, F. (2024). Exploring the impact of artificial intelligence in teaching and learning of science: A systematic review of empirical research. *Research in Science Education, 54*, 977–997. https://doi.org/10.1007/s11165-024-10176-3

Ayanwale, M. A., Adelana, O. P., Molefi, R. R., Adeeko, O., & Ishola, A. M. (2024). Examining artificial intelligence literacy among pre-service teachers for future classrooms. *Computers and Education Open, 6*, 100179. https://doi.org/10.1016/j.caeo.2024.100179

Bali, B., Garba, E. J., Ahmadu, A. S., Takwate, K. T., & Malgwi, Y. M. (2024). Analysis of emerging trends in artificial intelligence for education in Nigeria. *Discover Artificial Intelligence*, *4*, 110. https://doi.org/10.1007/s44163-024-00163-y

Centre for Multidisciplinary Research and Innovation, Sanusi, I. T., Agbo, F. J., Dada, O. A., Yunusa, A. A., Aruleba, K. D., Obaido, G., Olawumi, O., & Oyelere, S. S. (2024). Stakeholders' insights on artificial intelligence education: Perspectives of teachers, students, and policymakers. *Computers and Education Open, 7*, 100212. https://doi.org/10.1016/j.caeo.2024.100212

Cheung, K. K. C., Zerouali, A., Koenen, J., & Erduran, S. (2025). Do generative artificial intelligence (GenAI) and science education mix? A systematic review of the literature. *Studies in Science Education*. https://doi.org/10.1080/03057267.2025.2578091

Dwivedi, Y. K., Kshetri, N., Hughes, L., Slade, E. L., Jeyaraj, A., Kumar Kar, A., Baabdullah, A. M., Koohang, A., Raghavan, V., Ahuja, M., Albanna, H., Albashrawi, M. A., Al-Busaidi, A. S., Balakrishnan, J., Barlette, Y., Basu, S., Bose, I., Brooks, L., Buhalis, D., & Wright, R. (2023). So what if ChatGPT wrote it? Multidisciplinary perspectives on opportunities, challenges and implications of generative conversational AI for research, practice and policy. *International Journal of Information Management, 71*, 102642. https://doi.org/10.1016/j.ijinfomgt.2023.102642

Fadipe Bayo Michael, F. C. Uwaechia, Kate Uzoamaka Wilfred-Bonse, Ezekwudo Celestina Chinenye and Jibril Nma Mohammed (2024). Physics Teachers' Perception on the Adequacy of Infrastructure in the Evaluation of the Implementation of the Physics Curriculum Using Davis Process Model Among Unity Colleges in North Central Nigeria. *International Journal of Research in Library and Information Science (IJRLIS)* Volume 2, Issue 1, January-June, 2024, pp. 1–12, Article ID: IJRLIS_02_01_001 Available online at https://iaeme.com/Home/issue/IJCS?Volume=2&Issue=1 Journal ID: 8899-6754

Fadipe, B. M. (2025). Evaluation of community perception on the adequacy of infrastructure for the implementation of the physics curriculum using Davis process model among unity colleges in North Central Nigeria: Implications on education for sustainable development. *Journal of Education for Sustainable Development Studies*, 2(1), 103–110. DOI: 10.70232/ jesds. v2i1.18

Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education: Promises and implications for teaching and learning*. Center for Curriculum Redesign.

Kasneci, E., Sessler, K., Küchemann, S., Bannert, M., Dementieva, D., Fischer, F., Gasser, U., Groh, G., Günnemann, S., Hüllermeier, E., Krusche, S., Kutyniok, G., Michaeli, T., Nerdel, C., Pfeiffer, F., Poquet, O., Sailer, M., Schmidt, A., Seidel, T., & Kasneci, G. (2023). ChatGPT for good? On opportunities and challenges of large language models for education. *Learning and Individual Differences, 103*, 102274. https://doi.org/10.1016/j.lindif.2023.102274

Miao, F., & Cukurova, M. (2024). *AI competency framework for teachers*. UNESCO. https://doi.org/10.54675/ZJTE2084

Miao, F., & Holmes, W. (2023). *Guidance for generative AI in education and research*. UNESCO.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Ng, D. T. K., Su, J., & Ng, E. H. K. (2024). A systematic review of AI education in K-12 classrooms from 2018 to 2023: Topics, strategies, and learning outcomes. *Computers and Education: Artificial Intelligence, 6*, 100211. https://doi.org/10.1016/j.caeai.2024.100211

Ogunleye, B., Zakariyyah, K. I., Ajao, O., Olayinka, O., & Sharma, H. (2024). A systematic review of generative AI for teaching and learning practice. *Education Sciences, 14*(6), 636. https://doi.org/10.3390/educsci14060636

OECD. (2023). *OECD digital education outlook 2023: Towards an effective digital education ecosystem*. OECD Publishing. https://doi.org/10.1787/c74f03de-en

Peter Joy Abosede & Fadipe, Bayo Michael., (2023). Colleges of Education Science Teachers Awareness of E-Books in Sciences for Learning in Kaduna State. *Journal of Educational Studies Trend and Practices. (JESTP).* 26(8) 63- 72.

Sperling, K., Stenberg, C.-J., McGrath, C., Åkerfeldt, A., Heintz, F., & Stenliden, L. (2024). In search of artificial intelligence (AI) literacy in teacher education: A scoping review. *Computers and Education Open, 6*, 100169. https://doi.org/10.1016/j.caeo.2024.100169

Tenberga, I., & Daniela, L. (2024). Artificial intelligence literacy competencies for teachers through self-assessment tools. *Sustainability, 16*(23), 10386. https://doi.org/10.3390/su162310386

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly, 27*(3), 425–478. https://doi.org/10.2307/30036540

Yusuf, A., Pervin, N., Román-González, M., & Noor, N. M. (2024). Generative AI in education and research: A systematic mapping review. *Review of Education, 12*(2), e3489. https://doi.org/10.1002/rev3.3489

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education—Where are the educators? *International Journal of Educational Technology in Higher Education, 16*, Article 39. https://doi.org/10.1186/s41239-019-0171-0

Zhai, X., Chu, X., Chai, C. S., Jong, M. S.-Y., Istenic, A., Spector, J. M., Liu, J.-B., Yuan, J., & Li, Y. (2021). A review of artificial intelligence (AI) in education from 2010 to 2020. *Complexity, 2021*, Article 8812542. https://doi.org/10.1155/2021/8812542

Zhou, X., Li, Y., Chai, C. S., & Chiu, T. K. F. (2025). Defining, enhancing, and assessing artificial intelligence literacy and competency in K-12 education from a systematic review. *Interactive Learning Environments, 33*(10), 5766–5788. https://doi.org/10.1080/10494820.2025.2487538