AITIE
8th
INTERNATIONAL CONFERENCE & WORKSHOP ON INNOVATION, TECHNOLOGY & EDUCATION
THEME:
FROM AUTOMATION TO AUGMENTATION REIMAGINING TEACHING AND LEARNING ECOSYSTEMS IN THE AI ERA
5TH–8TH AUGUST 2026
MULTIPURPOSE HALL, FELELE CAMPUS
FEDERAL UNIVERSITY LOKOJA
KOGI STATE
– LOKOJA 2026 –

CONFERENCE PROCEEDINGS OF THE AITIE 8TH INTERNATIONAL CONFERENCE AND WORKSHOP ON INNOVATION, TECHNOLOGY AND EDUCATION (ICWITE, LOKOJA 2026)

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ISSN: 2636-5626 online

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Published by The Association for Innovative Technology Integration in Education

Hosting Partner:

Federal University, Lokoja, Kogi State, Nigeria.

Organized by:

Association for Innovative Technology Integration in Education **ICWITE, LOKOJA, 2026**

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AITIE

Creative minds innovate to transform the world.

They innovate through forward-thinking ideas to create the desired values.

Beyond the politics of educational research for certification lies the politics of educational research for transformation.

Only the network of dedicated and technology literate individuals can constructively integrate technology to support learning.

Through creative thinking, research and praxes we must Domesticate, Innovate and Integrate Technology for Instruction

INTERNATIONAL CONFERENCE AND WORKSHOP ON INNOVATION, TECHNOLOGY AND EDUCATION

This conference is dedicated to educators globally, the legends and pioneers who have made contributions into the integration of media in the Nigerian educational system and to the members of the Association for Innovative Technology Integration in Education (AITIE) who have the desire to facilitate learning in variety of educational settings through innovative and creative use of technology

Vision

To be the foremost professional association in the integration of technologies for teaching, learning, research and administrative purposes in conventional and distance education settings.

Mission

We seek to be a force for qualitative accessible education, through the promotion of scholarship and best practices in the design, development, use, and innovative management of technologies for effective teaching and learning in a variety of educational settings.

Core Values

The following principles guide our work and define the mission of AITIE:

- **access to quality education**: a commitment to access to quality education for all, irrespective of location, gender, race, religion, disability, etc., as education is a human right and an instrument for poverty alleviation and sustainable human development;
- **excellence**: promotion of quality research, teaching, learning, and life-changing scholarship and value-based service, through innovative use of technology
- **innovation and creativity**: encouragement of intellectual inquisitiveness through the promotion of technology for enhanced lifelong learning
- **teamwork**: encouragement of collaboration among individual and institutional members and promotion of shared values in the integration of information and communication technology in all aspects of education;
- **continuing professional education**: promotion of quality professional education for members and graduates already in the workforce;
- **association, institutions and industry collaboration**: encouraging closer social and economic ties among the Association, other professional associations, educational institutions, and the industry;
- **academic and professional integrity**: commitment to maintaining academic quality and standards, and integrity in all programmes of the association.
- **resources for teaching and learning**: commitment to providing resources for teaching, learning, research, and administration in conventional and distance education settings; and
- **Professionalism**: expertise and judgment of educational technology and related media professionals are critical to the successful integration of technology in education. AITIE maintains the highest professional standards and expects the status, compensation, and respect due to all professionals.

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PRESIDENTIAL ADDRESS AT THE 2026 AITIE CONFERENCE

WELCOME ADDRESS DELIVERED BY PROFESSOR AMOSA ISIAKA GAMBARI,

NATIONAL PRESIDENT, ASSOCIATION FOR INNOVATIVE TECHNOLOGY INTEGRATION IN EDUCATION (AITIE) ON THE OCCASION OF THE 8TH INTERNATIONAL CONFERENCE AND WORKSHOP ON INNOVATION, TECHNOLOGY AND EDUCATION

Holding from Wednesday 5th – Saturday 8th August, 2026 at the Multi-Purpose Hall,

Felele Campus, Federal University Lokoja, Kogi State, Nigeria.

PROTOCOL

I give thanks to Almighty Allah for this opportunity to welcome you, on behalf of the Association for Innovative Technology Integration in Education (AITIE), to the 8th International Conference and Workshop on Innovation, Technology and Education. We are here in Lokoja, the confluence town, for a week that will help shape how we teach and learn in the age of Artificial Intelligence.

I sincerely thank our Chief Host, Professor Gbenga Solomon Ibileye, MNAL, FESAN, FLAN, the Vice Chancellor of Federal University Lokoja, and the entire Management, Staff and Students of this great institution, for hosting this conference in the Multi-Purpose Hall, Felele Campus. Sir, we are grateful for your generosity and hospitality. You provided comfortable accommodation, reliable transportation and smooth logistics for us throughout our stay. On behalf of AITIE, we say a big thank you for your support and for hosting this 8th edition.

I am pleased to welcome our Keynote Speaker, Professor Sunday Olusanya Olatunji (AADAM), Professor of Artificial Intelligence and Machine Learning, and pioneer Dean, Faculty of Computing, Adekunle Ajasin University, Akungba-Akoko, Ondo State. His keynote lecture will set the tone for this conference.

We also welcome our two Lead Paper Presenters: Professor David Kolawole Omole, former Dean, Faculty of Education, Federal University Lokoja; and Professor Achimugu Lawrence, Dean, Faculty of Education, Prince Abubakar Audu University (PAAU), Anyigba. Both will deliver papers that will deepen our understanding of how automation gives way to augmentation in our classrooms and institutions.

I welcome our Workshop Facilitators: Mr. Olabisi Faith Ayanfeoluwa, who led Track 1 on Human-AI Co-Design of Contextual and Sustainable Open Educational Resources; and Mrs. Jennifer

Woruka, who led Track 2 on Designing AI-Augmented Assessment for Authentic Learning and Feedback. These workshops gave participants practical skills to take back to their institutions.

I commend our National Officers' Committee and Local Organising Committee for their hard work in bringing this conference to life: Dr. H. O. Bolaji, Chairman NOC; Dr. M. A. Jimoh, Secretary NOC; Dr. T. E. Adebayo, Chairman LOC; Dr. H. M. Muftawu, Secretary LOC; and all other members of the LOC. AITIE remains grateful for your dedication.

We warmly welcome all our invited guests, partners, discussants and stakeholders who have honoured our invitation. To every participant who is virtually or physically present here, thank you for your presence and your commitment to advancing innovation in education.

My special appreciation goes to our mentor and founder of AITIE, Professor Mudasiru Olalere Yusuf. Sir, you are the academic father and grandfather of us all, our mentor and grandmentor, a teacher of teachers and a professor of professors. You have trained generations of scholars who have gone on to train others across our universities and colleges of education. AITIE remains one of the lasting legacies of your vision and hard work. We remain grateful for your leadership and for the strong foundation you laid for this Association.

The theme of this year's conference, “From Automation to Augmentation: Reimagining Teaching and Learning Ecosystems in the AI Era,” is very timely. For years, we focused on automating routine tasks and moving content online. Today, the question is no longer whether AI will affect education, but how we can design AI to support, not replace, the human side of teaching and learning.

Our twelve sub-themes cover important areas such as AI-augmented instructional systems, generative AI for courseware, learning analytics, ethical AI, immersive media, and infrastructure and policy readiness. Together, they give us a roadmap for innovation that is practical, humane and grounded in sound teaching practice. Furthermore, our two workshop tracks equipped us with usable skills. Track 1 showed us how to build learning materials suitable and appropriate to our context, while Track 2 sharpened our ability to assess what truly matters in our learners' growth.

Dear colleagues, we cannot afford to be left behind in this fast-changing digital world. We must embrace innovation, not only in our policies, but in our daily practice in classrooms, laboratories and offices. As educators and technology integrators, it is our responsibility to build a future of learning that is efficient without losing its human touch. Therefore, I encourage everyone to participate actively in the plenaries, lead paper presentations, workshops and networking sessions this week. This conference is a place to exchange ideas and build partnerships that will benefit our institutions long after we leave this hall.

Mr. Vice Chancellor, distinguished guests, ladies and gentlemen, I am confident that this 8th edition of our conference will be impactful, memorable, and transformative. Let us continue to build bridges between technology and education for the benefit of all. I wish everyone fruitful deliberations, good networking and a pleasant stay here in Lokoja. Please feel at home, and take back the knowledge and inspiration that will bring positive change to your institutions and communities.

Once again, we sincerely appreciate the Vice Chancellor's leadership and commitment to the success of this conference. We pray that Almighty God continues to grant you wisdom, good health and capacity to provide purposeful and good leadership to Federal University Lokoja, its management, staff and students. To all our invited guests, speakers and participants, I wish you journey mercies to your various destinations.

Thank you, and God bless you all.

Prof. Amosa Isiaka Gambari

National President, AITIE

Keynote and Lead Papers

- **Keynote Speaker: Prof. Sunday Olusanya Olatunji (AADM)**

  (Professor of Artificial Intelligence and Machine Learning / Pioneer Dean, Faculty of Computing, Adekunle Ajasin University, Akungba Akoko, Ondo State, Nigeria)

Lead Paper 1

FROM AUTOMATION TO AUGMENTATION: REIMAGINING TEACHING AND LEARNING ECOSYSTEMS IN THE AI ERA

Prof. David Kolawole Omole
Department of Educational Foundations
Federal University Lokoja, Kogi State Nigeria.

Abstract

The rapid infusion of Artificial Intelligence (AI) into global educational frameworks has sparked a critical evolutionary shift: moving away from mere automation the mechanization of administrative and repetitive pedagogical tasks toward augmentation, where human intelligence and machine capability work in tight synergy. This lead paper addresses this paradigm shift within the context of the Nigerian educational ecosystem. Using current institutional realities including the Federal University Lokoja's landmark structural pivot toward becoming a TETFund-backed Centre of Excellence in AI, Robotics, and Cyber Sciences. This paper maps out an operational model for an AI-augmented educational architecture. It examines the pitfalls of using AI solely as a replacement for human tasks (automation), counters with the cognitive benefits of human-AI collaboration (augmentation), addresses structural challenges specific to Sub-Saharan Africa (the "infrastructure tax"), and outlines a policy framework to prepare Nigerian educators for an AI-integrated tomorrow.

Introduction

We are gathering at the Felele Campus of the Federal University Lokoja at a deeply symbolic moment. Just weeks ago, the National Universities Commission (NUC) approved groundbreaking degree programmes here in Artificial Intelligence and Data Science, running alongside a historic 3-billion-Naira TETFund commitment to establish a regional Centre of Excellence in AI, Robotics, and Cyber Sciences on this very ground.

This tells us one thing clearly: **AI in Nigerian education is no longer an abstract future concept; it is an active institutional reality.**

Yet, as educational stakeholders, instructional designers, and media specialists within AITIE, we face a defining choice in how we implement this technology:

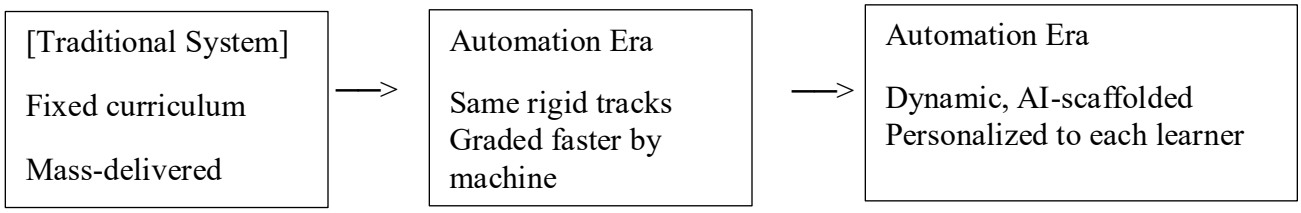
- Do we use AI to automate our old, industrial-era models of schooling?
- Or do we use AI to augment the unique cognitive and emotional strengths of our human educators and students?

This paper argues that automation alone risks embedding systemic inequalities deeper into our system, while an intentional pivot to *augmentation* offers a real chance to leapfrog historic barriers and revitalize education across Africa.

Automation vs. Augmentation: A Conceptual Shift

To build a shared foundation for this conference's workshops, we must explicitly separate these two approaches:

- **Educational Automation** treats AI as an optimization tool to replace human labour. It focuses heavily on efficiency, such as automated grading systems, attendance trackers, and basic chatbot answering scripts. While helpful for relieving administrative burdens, automation alone leaves the fundamental pedagogy untouched. It treats the student as a consumer of fixed content and the teacher as an administrative manager.
- **Educational Augmentation** treats AI as an essential cognitive collaborator. It focuses on expansion, pairing an educator's emotional intelligence, ethical guidance, and cultural intuition with AI's ability to analyze vast data patterns, personalize learning paths in real time, and generate interactive scaffolding.



Instead of asking, *"How many teacher hours can this tool save?"* an augmentation mindset asks, *"How can this tool help a teacher deeply understand and support a classroom of 80 diverse learners?"*

Designing an Augmented Learning Architecture

An augmented learning ecosystem rests on three main structural pillars, turning everyday classrooms into responsive learning environments:

1. **Intelligent Tutoring & Hyper-Personalization**

In classrooms with high student-to-teacher ratios, personalized attention is incredibly difficult to achieve. AI-driven adaptive learning systems solve this by assessing a student's current knowledge gaps, reading pace, and cognitive style. The AI can then alter content delivery, adjust problem difficulty, and suggest targeted interventions.

2. **Human-AI Co-Designed of Open Educational Resources (OER)**

Rather than relying purely on generic, imported textbooks, Nigerian educators can collaborate with generative models to co-create contextualized instructional packages. Teachers provide the local cultural context, localized case studies, and pedagogical goals, while AI supports rapid prototyping, asset creation, and multi-language translations.

3. Authentic Continuous Assessment

Moving away from high-stakes, memory-based examinations, an augmented framework uses continuous, formative analytics. It tracks a student's problem-solving process, critical thinking patterns, and collaborative inputs over time, giving educators a rich, multi-dimensional view of true mastery.

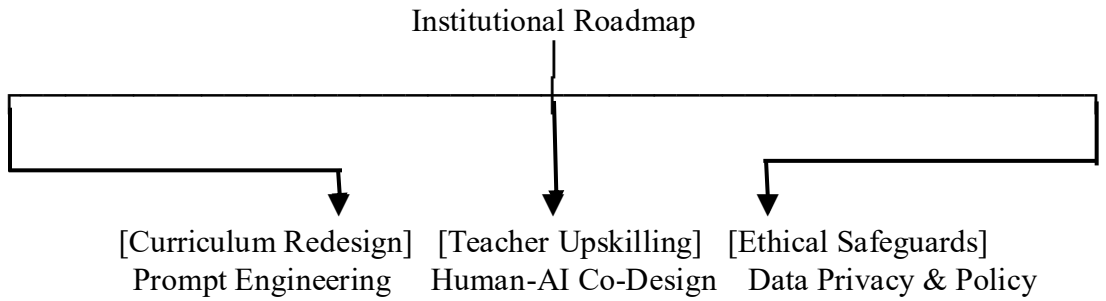
Addressing the Sub-Saharan Infrastructure Tax

We cannot talk about advanced technology integration without confronting the practical realities faced by Nigerian institutions. Implementing AI systems across our 36 states requires navigating a specific set of local challenges:

Structural Barrier	Educational Impact	Augmentation Strategy
Intermittent Power Grid	Power drops interrupt cloud-based learning sessions.	Deploy edge-AI models that run locally on low-power devices without needing a constant internet connection.
High Cost of Bandwidth	High data costs lock students out of resource-heavy platforms.	Prioritize text-based, highly compressed AI models optimized for asynchronous and mobile-first learning.
The Digital Divide	Rural and underfunded schools risk falling further behind.	Direct national investments (like TETFund) toward building centralized, shared cloud computing resources for public institutions.

Actionable Roadmap for Nigerian Higher Education

To shift our institutions from passive users to active leaders of educational technology, we must commit to a clear, practical strategy:



1. Re-engineer Teacher Training Curricula

We need to update our Faculty of Education programmes nationwide. Prompt engineering, educational data analytics, and human-AI co-design principles should be core requirements, not optional electives. Educators must learn to treat AI as a teaching assistant rather than a threat.

2. Formulate Context-Specific Ethical AI Frameworks

We must design clear institutional guidelines addressing data privacy, algorithmic bias, and academic integrity. These frameworks need to protect student data while actively encouraging responsible experimentation with AI tools.

3. Establish Localized Innovation Hubs

Following the example set by the Federal University Lokoja, universities across the country should build dedicated spaces where computer scientists, instructional designers, and classroom teachers can collaborate to build home-grown educational software tailored to our local curricula.

Conclusion: A Call to Action for AITIE 2026

Distinguished colleagues, the era of AI-driven education is here. If we look at this transition through the narrow lens of *automation*, we miss the larger opportunity. We risk ending up with classrooms that are highly efficient but completely detached from real, meaningful learning. As we begin this AITIE conference, let us dedicate ourselves to building an augmented future. Let us leverage tools like Federal University Lokoja's new Centre of Excellence to design learning environments that combine the processing power of AI with the irreplaceable empathy, creativity, and dedication of the African teacher.

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Lead Paper 2

(Dean, Faculty of Education, Prince Abubakar Audu University (PAAU), Anyigba)

Making Artificial Intelligence (AI) Works in Nigerian Universities

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Abstract
The discourse on digital transformation in Nigerian higher education has traditionally focused on expanding information and communication technology (ICT) infrastructure through increased internet bandwidth, fibre-optic connectivity, and computer laboratories. While these investments have improved digital access, they are insufficient for preparing universities to harness the transformative potential of artificial intelligence (AI). The emergence of generative AI, machine learning, and intelligent learning systems requires a shift from infrastructure-centered digitalization to institution-wide AI readiness that supports teaching, learning, research and governance. This paper defines artificial intelligence and explores the application of Artificial Intelligence (AI) in higher education in Nigeria, examining its potential benefits such as smart, tutoring systems, administrative efficiency, predictive analysis, virtual learning, research support, security and surveillance. The paper highlights the challenges of artificial intelligence in Nigerian higher education which includes: lack of policy framework, ethical and privacy concern, inadequate infrastructure, limited technical expertise, high cost of implementation, resistance to change and epileptic energy supply. To find solutions to these challenges the paper discusses the way forward for making artificial intelligence work in Nigeria universities as follows: formulation of adequate policy for promotion of AI, development of comprehensive data protection policies, deliberate investment in AI infrastructural facilities, establishment of AI literacy, creating alternative funding strategies fostering the culture of innovation and provision of alternative energy solution. It concludes that while the road to AI adoption is Nigerian universities may be challenging it is both necessary and inevitable and thus, to move forward, deliberate and coordinated efforts are required from our stakeholders

Keywords: *application, artificial intelligence, challenges, higher education, institutional challenges, prospects and solutions*

Introduction

Artificial intelligence (AI) has emerged as the latest disruptive technologies influencing higher education in the twenty-first century. Advances in generative AI, large language models, machine learning and learning analytics are repositioning teaching, assessment, research and institutional

governance across universities globally (Holmes, 2019). AI is not only transforming traditional pedagogical practices but also enhancing administrative efficiency, research capacity and learner engagement (Holmes, 2019). With the increasing AI systems and their subsequent adaptation into our daily lives, educational system is witnessing upsurge in personalized support learning, curriculum redesign, academic advising, research productivity and evidence-informed institutional decision-making (UNESCO, 2021). Consequently, universities are moving beyond conventional digitalization initiatives toward comprehensive AI readiness strategies that integrate technological infrastructure with organizational capability, ethical governance and human capacity development for a greater educational process (Benaim & Lalloo, 2021).

Artificial intelligence refers to intelligence exhibited by machines instead of people in a faster and comfortable way. Artificial intelligence, according to Verma (2019), is the study of intelligent software and robots that are able to reason, learn, gather information, communicate, operate and perceive objects. Ahmad et al. (2021) state that artificial intelligence (AI) was first utilized by John McCarthy in 1955 and was described as the ability to make a computer behave in a way that a human would be considered intelligent if it were doing so. According to Ahmad et al. 2021). Artificial intelligence (AI) describes systems that are capable of carrying out cognitive tasks like learning and problem-solving that are connected to the human mind. It involves a variety of tasks, including as creating artificial intelligence for computers that can recognize speech, learn, plan, and solve problems. These systems are intended to function with different degrees of independence. Therefore, programming machines to think and behave like humans is the definition of artificial intelligence (AI). According to these definitions, it can be deduced that artificial intelligence (AI) in the education sector is a well-designed technology that provides a flexible environment, chances for cooperation, options and control over the learning process, enabling both teachers and students to pursue learning effectively.

Digital technological transformation initiatives in Nigeria higher education, have historically emphasized the need for an expanded internet connectivity, computer laboratories and computer-based testing facilities. While these investments have improved access to digital technologies, unfortunately, they remain insufficient for preparing universities to deploy AI responsibly and effectively beyond conventional digitalization initiatives. There is a need for universities and the sponsors agencies like the National intervention agencies such as the Tertiary Education Trust

Fund (TETFund) to make a paradigm shift in strengthening tertiary education infrastructure, creating opportunities for universities to reposition future interventions toward AI-enabled institutional transformation rather than conventional ICT expansion. International policy discussions is increasingly advocating a human-centred approach to AI adoption in education, emphasizing that AI should enhance rather than replace educators' professional judgement, creativity and pedagogical expertise. UNESCO's guidance on generative AI argues that institutions should prioritize human agency, ethical governance, equity and capacity building when integrating AI into educational systems. This perspective aligns with the concept of human capacity augmentation proposed in this paper, which positions AI as an intelligent partner supporting lecturers in instructional design, formative assessment, student support and learning analytics rather than as a substitute for academic professionals.

Globally, there has been an increased policy focus on leveraging AI for educational advancement. UNESCO (2021) has called for the integration of AI in education policies to ensure that all countries benefit equitably from these technologies. In response, nations such as China, the United States, and some countries in Africa like Rwanda and South Africa are developing frameworks to promote responsible and inclusive AI integration in higher education (Wang & Cheng, 2020; Benaim & Lalloo, 2021; World Bank, 2020). Nigeria, however, has yet to establish a national strategy specifically focused on AI in education, leaving most higher institutions without a clear roadmap for implementation (Olumide & Ojo, 2022).

In the context of developing nations like Nigeria, the potential for AI to bridge gaps in access, quality, and relevance of good and quality education cannot be overemphasized. Nigeria, with its rapidly expanding population of youth and a growing need for higher education access, is at a strategic position to benefit from the innovations driven by AI (Adebayo & Salako, 2021; Olayemi & Omotayo, 2022). The use of AI-powered tools such as chatbots, adaptive learning platforms, and data analytics can help address challenges of overcrowded classrooms, shortage of academic staff, and poor service delivery in Nigerian universities (Onyeaso & Eze, 2022). Furthermore, AI has the capacity to democratize education by enabling remote learning, supporting students with special needs, and enhancing teacher effectiveness (Mhlanga & Moloi, 2020). In light of the above, there is a pressing need to examine the current state of AI application in Nigerian higher education,

identify the major challenges impeding progress, and explore viable pathways to scale up adoption. This includes not only infrastructural and technical considerations but also the development of human capital, ethical frameworks, and strategic partnerships. A holistic approach that aligns national policy with institutional strategies and global trends is imperative to drive sustainable integration of AI in Nigeria's higher education landscape (Oke & Olatunji, 2023; Chaka, 2020).

The most promising application of artificial intelligence in education is the personalization of instruction and learning resources. Customizing education to meet the individual needs and skills of every student is the aim of customized learning. Artificial intelligence (AI) programs can foresee, recommend, and determine the next steps in the learning process based on data from individual students. They can also identify educational materials and methods that are suited for each individual student's level. Artificial intelligence (AI) tools assist kids in learning at their own pace and provide guidance to teachers on how best to assist them. Additionally, artificial intelligence (AI) fosters a positive atmosphere by offering a backdrop that is conducive to students' learning preferences and methods. In higher education settings, tutors also oversee AI. Teachers can use AI to create a learning environment where students can understand concepts more deeply. Giving all pupils more equitable access to education is another potential application of AI in education, which has proven difficult for many emerging and impoverished nations. According to the OECD (2020), one of the global goals outlined in SDG Goal 4 is inclusive education. This goal aims to guarantee equal access to all educational levels for all individuals, including those with impairments. Previous studies have shown that AI systems are effective in helping students with disabilities—such as those with visual or hearing impairments or social skills—to benefit from schooling. Wearables with AI capabilities, for example, can help vision impaired kids learn to read books, identify faces, and socialize with others in their community. There are systems in place designed to help children with a range of difficulties. Thanks to robots, augmented and virtual reality (AR/VR), and other AI powered technology, students with physical or mental health difficulties can study and participate more in class. For example, kids with autism can explore and enhance their social skills in a classroom setting by collaborating and interacting with virtual characters and digital objects (OECD, 2020).

AI has also demonstrated potential for early student disability problem diagnosis. According to Drigas and Rodi-Eleni (2012), AI-based methods have demonstrated promise in the early diagnosis of dyslexia, for instance. One well-known example is the Swedish startup "Lexplore," which created a system that swiftly looks for pupils who might be at danger and uses reader eye movements to identify dyslexia. Furthermore, attention deficit hyperactivity disorder (ADHD) and autistic spectrum disorder have been successfully diagnosed using AIbased methods. Specifically, it appears that child-robot interaction makes new diagnostic and special needs educational applications possible (Scassellati, et al., 2012).

Children's cognitive development has been found to benefit from AI. Drigas and Rodi-Eleni (2012) state that there are three essentially different applications of AI, and that each of these applications may have a different impact on the cognitive development of adults and children. AI can enhance existing capabilities. Certain human cognitive capacities may become less valuable or perhaps outdated as a result of AI. For example, because AI can now convert speech to writing and vice versa, dyslexia may not have the same societal significance as it once did. While persons with dyslexia and dyscalculia might benefit from AI, it may be difficult to predict how technology will impact society as a whole. For example, computers can assist people with adding and multiplying numbers, but if they grow overly reliant on them, it may be more difficult for them to grasp more sophisticated mathematical ideas that need number sense and mental arithmetic.
This is accomplished by automating procedures including management, evaluation, feedback, and plagiarism detection. Additionally, AI might help teachers in other ways, such as by evaluating student data, forecasting academic success, and offering solutions to overcome learning obstacles. AI also gives teachers more understanding of their pupils' progress. Additionally, AI can provide educators with the necessary and sufficient knowledge on the unique qualities of every student that may have an impact on their future job pathways.

Benefits of Artificial Intelligence in Higher Education in Nigeria

Artificial Intelligence (AI) holds immense potential to transform the landscape of higher education in Nigeria by enhancing teaching, learning, research, and administrative processes. With increasing demands for quality education and the need to address systemic inefficiencies, Nigerian universities and colleges stand to gain significantly from adopting AI-driven

technologies. The following subsections outline key applications of AI in the Nigerian higher education context.

1. **Smart Tutoring Systems**: AI-based tutoring systems are revolutionizing how students interact with course materials and instructors. These systems utilize machine learning algorithms to assess students' prior knowledge, monitor progress in real time, and adapt instructional content accordingly. By offering customized feedback and guidance, AI-powered tutoring systems can help bridge learning gaps, especially in large classrooms where personalized attention is difficult to provide. In Nigeria, where student-to-teacher ratios remain high often exceeding 1:100 in many public universities smart tutoring systems can serve as invaluable academic assistants. For example, platforms such as Squirrel AI and Carnegie Learning, which have been deployed in other countries, could be localized and adapted to the Nigerian context (Benaim & Lalloo, 2021). Such systems can also be programmed to offer multi-language support and address challenges in under-resourced regions, thus promoting inclusive learning.
2. **Administrative Efficiency**: AI is capable of enhancing operational efficiency by automating routine administrative tasks, thereby saving time and reducing human error. In Nigerian universities, common administrative activities such as processing applications, handling course registrations, scheduling examinations, and responding to student queries can be handled more effectively with AI-powered solutions. Chatbots, for instance, can provide 24/7 responses to frequently asked questions, reducing the workload of administrative staff. Natural Language Processing (NLP) models integrated into university websites or portals can interact with students, handle inquiries about admissions, course availability, deadlines, and even resolve complaints (Okoye & Ezema, 2020). Additionally, Robotic Process Automation (RPA) can be used for automating the generation of transcripts, certificates, and payroll systems, which are often bogged down by bureaucratic inefficiencies in Nigerian institutions.
3. **Predictive Analytics:** Another significant application of AI in higher education is in the area of predictive analytics. AI systems can analyze large volumes of student data to identify trends and predict future behaviors, such as the likelihood of academic success or dropout risk. This allows for early interventions that can support students at risk of failure or disengagement. In Nigeria, where retention and graduation rates are concerning in many

universities, predictive analytics could be a game-changer. For instance, by analyzing attendance patterns, grades, and engagement with course materials, AI can alert academic advisors or faculty members about students who may need additional support. Predictive tools can also aid in strategic planning, such as forecasting enrollment numbers, optimizing resource allocation, and improving curriculum design (Adebayo & Salako, 2021).

4. **Virtual Learning and Remote Classrooms:** The COVID-19 pandemic exposed significant weaknesses in Nigeria's capacity for remote learning. AI can enhance the virtual learning experience by facilitating adaptive learning platforms, intelligent virtual assistants, and automated grading systems. These tools support individualized learning pathways, allowing students to learn at their own pace and receive immediate feedback. For instance, AI-driven platforms like Coursera, Edmodo, and Khan Academy utilize algorithms that recommend resources based on learners' needs. Nigerian universities can integrate similar AI solutions into their Learning Management Systems (LMS) to improve student engagement and outcomes. Moreover, AI can provide subtitles, translations, and content summarization—essential tools for distance learners, especially those in rural and underserved areas (UNESCO, 2021). The integration of AI in virtual learning also supports educators. With AI-generated analytics, lecturers can assess which students are actively engaging with course content and tailor their support accordingly. These systems can flag knowledge gaps and provide suggestions on how to address them.

5. **Research and Academic Support:** Academic research is the backbone of higher education, and AI can significantly accelerate and enhance the research process. AI-powered tools such as natural language processing, machine learning, and semantic search engines can assist researchers in discovering relevant literature, analyzing data, and visualizing complex results. AI can also detect patterns and generate hypotheses, helping researchers in multidisciplinary fields to develop more robust models. In Nigerian universities where access to current research resources and laboratory equipment is often limited, AI tools can fill critical gaps. For example, platforms like Zotero, EndNote, Grammarly, and Turnitin, which use AI for citation management, grammar correction, and plagiarism detection, are already in use. These tools not only improve the quality of academic writing but also uphold academic integrity (Oke & Olatunji, 2023). Additionally, AI applications in language processing can aid postgraduate students and researchers whose academic writing may be

limited by proficiency in English. AI-assisted writing support systems can help in improving clarity, coherence, and academic tone in thesis and journal submissions.

6. **Security and Surveillance:** As security becomes a growing concern in Nigerian higher institutions due to threats such as examination malpractice, cultism, and in some cases terrorism AI has found increasing application in enhancing campus safety. AI-powered facial recognition systems, smart cameras, and real-time monitoring software can be employed to control access to examination halls, dormitories, and sensitive facilities. Institutions like Covenant University and the University of Lagos have begun experimenting with advanced surveillance systems to prevent unauthorized access and curb exam-related fraud. These AI tools can detect suspicious behavior, identify individuals on watchlists, and alert security personnel instantly (Ogunlade & Usman, 2022). Furthermore, AI can play a role in maintaining academic integrity. During online examinations, AI-driven proctoring software can monitor students through webcams, track screen activity, and flag anomalies in real time. While such tools raise important ethical questions regarding privacy, their careful implementation can help in preserving academic standards in virtual environments.

Challenges of Artificial Intelligence in Nigerian Higher Education

While the potential benefits of Artificial Intelligence (AI) in higher education are well recognized, the adoption and integration of these technologies in Nigeria face numerous challenges. These challenges are structural, technical, financial, and ethical in nature, posing serious impediments to the full-scale deployment of AI-driven solutions in universities and colleges. Understanding these barriers is critical for formulating strategies to overcome them. The challenges are:

1. **Lack of Policy Framework:** Despite increasing interest in AI across Africa, Nigeria currently lacks a national policy specifically dedicated to the integration of AI in the education sector. The absence of a coherent policy framework means that individual institutions are left to chart their own course without guidance, support, or standardization. This often leads to fragmented efforts, duplication of initiatives, and inconsistent levels of adoption (Benaim & Lalloo, 2021). Furthermore, key agencies such as the National Universities Commission (NUC), the Federal Ministry of Education, and the National Information Technology Development Agency (NITDA) have yet to develop a coordinated

strategy to mainstream AI in higher education. Without clear policy direction, it becomes difficult to attract investments, mobilize resources, or monitor progress in AI integration.

2. **Ethical and Privacy Concern:** The implementation of AI in higher education raises important ethical and legal questions, particularly concerning data privacy, algorithmic bias, surveillance, and informed consent. In Nigeria, these issues are even more complex due to the absence of comprehensive data protection laws and guidelines for ethical AI use in education (UNESCO, 2021). For example, AI systems that track student behavior or academic performance may inadvertently infringe on students' privacy if data is collected or used without proper consent. Similarly, facial recognition technologies and AI proctoring tools used during online examinations can lead to concerns about surveillance and misuse of biometric data. Moreover, AI algorithms trained on biased datasets may produce unfair outcomes, particularly affecting marginalized or underrepresented student groups. These ethical issues must be addressed through well-defined regulatory frameworks and institutional policies that prioritize fairness, transparency, and accountability.
3. **Inadequate Infrastructure:** The implementation of AI systems requires robust ICT infrastructure, including reliable internet connectivity, modern computing equipment, cloud computing platforms, and uninterrupted power supply. Unfortunately, many Nigerian universities, particularly those in rural or semiurban areas, struggle with poor digital infrastructure (Ogunlade & Usman, 2022). Broadband penetration remains low, and access to high-speed internet is inconsistent, making it difficult to support real-time AI applications such as intelligent tutoring systems or cloud-based learning platforms. Moreover, most universities still operate with outdated hardware and software, which are incompatible with modern AI algorithms and systems. The lack of smart classrooms, data centers, and secure servers further increase the problem. These infrastructural deficits not only slow down adoption but also reduce the effectiveness and scalability of AI innovations within the education sector. The integration of AI in education requires an environment with well-developed infrastructural facilities and trained experts in AI.
4. **Limited Technical Expertise:** The successful deployment of AI tools requires a skilled workforce capable of designing, developing, and maintaining such systems. In Nigeria, the shortage of AI professionals such as data scientists, machine learning engineers, and

AI ethicists poses a major constraint. Many academic institutions do not offer specialized training in AI, and existing staff often lack the technical competencies to implement and manage AI projects (Adebayo & Salako, 2021). Furthermore, most educators and administrative personnel are not exposed to continuous professional development in emerging technologies. The lack of training programs or partnerships with tech companies means that university staff are not adequately equipped to leverage AI for teaching or administration. This skills gap limits innovation and prevents institutions from exploring the full spectrum of AI capabilities.

5. **High Cost of Implementation:** AI systems are capital-intensive, requiring substantial investment in both hardware and software. The costs associated with acquiring AI platforms, setting up infrastructure, training staff, licensing software, and conducting regular maintenance are often beyond the financial capacity of many Nigerian public universities. Given the chronic underfunding of the education sector in Nigeria, it becomes extremely difficult for institutions to allocate sufficient resources to AI deployment (Oke & Olatunji, 2023). For example, AI-powered Learning Management Systems (LMS) with adaptive learning capabilities cost significantly more than standard LMS. Similarly, AI-enabled surveillance and security systems are more expensive than traditional CCTV setups.
6. **Resistance to Change:** Beyond technical and financial constraints, human factors such as resistance to change also pose significant challenges. Many academic and administrative staff in Nigerian universities are accustomed to traditional methods of teaching, learning, and management. As such, they may be reluctant to embrace new technologies that they perceive as disruptive or complex (Okoye & Ezema, 2020). particularly among academic and administrative personnel, this resistance can be addressed through inclusive change management strategies. This resistance is often fueled by fear of job displacement, especially when AI is introduced to automate tasks such as grading, scheduling, or administrative support. In some cases, there is also a cultural or generational divide where older faculty members feel alienated by new technological trends. This lack of enthusiasm for innovation hampers institutional transformation and slows the adoption of AI tools.

7. **Epileptic energy supply:** Electricity reliability represents one of the most significant barriers to AI adoption in Nigerian universities. Unlike conventional ICT applications, AI systems require continuous computing operations, particularly where institutions seek to host local AI models, maintain institutional databases, or operate analytics platforms. Dependence on unstable national electricity supply creates risks including: server interruptions; hardware damage; inconsistent learning platform availability; increased operational costs.

Way forward for making Artificial Intelligence work in Nigeria Universities

1. **Government should formulate adequate policy for promotion of AI:** The absence of a national AI policy tailored to the education sector necessitates the urgent development of a comprehensive strategic framework. Government bodies responsible for education and technology should collaborate to formulate guidelines that promote the responsible adoption of AI in Nigerian higher institutions. These policies should provide clarity on standards, priorities, ethical boundaries, and performance metrics. Universities should be supported in developing institutional AI strategies aligned with national goals, including digital transformation, inclusive education, and research development. A central coordinating body could be established to monitor implementation, share best practices, and facilitate resource-sharing across institutions. Policymakers should create a conducive regulatory environment encouraging innovation while addressing ethical considerations such as data privacy, algorithmic transparency, and accountability, along with formulating national AI strategies to outline long-term goals and investment priorities in AI research and development.
2. **Development of comprehensive data protection policies by government and institutions:** Ethical concerns surrounding the use of AI in higher education must be addressed through the establishment of clear institutional guidelines on data governance, user consent, transparency, and fairness. Universities should develop comprehensive data protection policies that define the scope of data collection, usage, and storage related to AI systems. It is essential to establish ethics committees to oversee the implementation of AI tools and ensure compliance with best practices in privacy and equity. Educating both students and staff on the responsible use of AI technologies can foster trust and promote ethical behavior. Provisions should also be made to audit AI systems periodically to detect

and rectify algorithmic bias or misuse. Universities must therefore establish clear policies regarding: acceptable AI use; data ownership; algorithmic transparency; cyber security; student consent; intellectual property protection. Without effective governance, AI adoption may create new forms of inequality and institutional vulnerability. An AI-ready institution requires a unified data architecture involving: integrated Student Information Systems (SIS); secure institutional databases; data standardization protocols; application programming interfaces (APIs); cyber security mechanisms. The objective is not merely collecting more data but creating meaningful, ethical, and usable institutional intelligence.

3. **Government and University should invest in infrastructural facilities for AI implementation:** One of the most critical impediments to the adoption of AI in Nigerian higher education is the lack of enabling infrastructure. Investment in infrastructure, where governments and university management allocate resources for building state-of-the-art AI labs, acquiring cutting-edge computing equipment and upgrading network infrastructure to support AI research. Universities must prioritize the development of modern computer laboratories, campus-wide broadband connectivity, uninterrupted power supply, and access to cloud-based platforms. Government agencies should work in collaboration with private sector partners to fund the expansion of digital infrastructure across campuses. In addition, institutions should adopt scalable and cost-effective technologies, including open-source AI tools, which can operate efficiently within limited resource environments. Equipping academic environments with the technological foundation necessary for AI will set the stage for long-term digital transformation. The Tertiary Education Trust Fund (TETFund) remains one of the most significant drivers of infrastructure and academic development in Nigerian public tertiary institutions. Historically, TETFund interventions have focused on physical infrastructure, research support, academic staff development, and institutional capacity improvement. However, the emergence of AI requires a strategic expansion of intervention priorities. Rather than viewing digital infrastructure as an additional cost, AI capability should be considered a strategic investment in institutional competitiveness, research productivity, and national development.
4. **Establishment of Faculty AI literacy:** AI integration requires academic staff who possess both disciplinary expertise and AI literacy. Without adequate professional development, lecturers may either reject AI technologies due to fear and

misunderstanding or use them in inappropriate ways that compromise academic standards. Therefore, Nigerian universities require a transition from ICT availability to institutional AI capability. Although technological infrastructure is essential, human capacity remains the most important determinant of successful AI adoption. Previous experiences with educational technology demonstrate that inadequate teacher preparation remains one of the greatest barriers to effective technology integration (Ertmer & Ottenbreit-Leftwich, 2010). AI introduces new competency requirements beyond traditional digital literacy. Academic staff require knowledge of AI capabilities and limitations; prompt engineering; AI-supported instructional design; ethical AI use; evaluation of AI-generated information; redesign of assessment practices. Faculty AI literacy is particularly important because lecturers serve as mediators between technology and students. Their beliefs, competencies, and attitudes significantly influence whether AI becomes an effective educational resource or an underutilized innovation. Rather than banning AI because of concerns about plagiarism, universities should develop responsible AI literacy programs that prepare students and staff to use AI critically and ethically. Assessment systems should also evolve from relying heavily on product-based assignments toward approaches that evaluate learning processes, creativity, reflection, practical application, and oral demonstration.

5. **Universities should create alternative funding strategies:** Although AI technologies are typically resource-intensive, creative funding strategies can mitigate the financial burden on institutions. Universities should actively seek alternative funding through grants, research collaborations, and public-private partnerships. The establishment of technology endowment funds can provide long-term financial support for AI initiatives. Institutions may also negotiate subsidized access to AI platforms with technology vendors or adopt freemium software models that allow incremental scaling. Implementing AI in phases starting with high-impact, low-cost areas such as administrative automation or e-learning support can help institutions manage costs while demonstrating value to attract further investment. Without targeted funding or budgetary prioritization, it is unlikely that institutions will be able to afford the long-term costs of AI adoption. Despite the challenges, some Nigerian universities have begun to explore the potential of AI in various domains. For example, the University of Lagos recently

launched a research center focused on AI and machine learning applications in healthcare, agriculture, and finance. This initiative aims to foster interdisciplinary collaboration among researchers and industry partners to address societal challenges using AI-driven solutions Okeke (2020). Similarly, the African University of Science and Technology (AUST) in Abuja has established partnerships with leading technology companies to train students in AI and data science. Through industry-sponsored projects and internships, students gain practical experience in developing AI applications for real-world problems. These initiatives not only bridge the skills gap but also facilitate technology transfer and knowledge exchange between academia and industry (Adewale, et al 2021).

6. **Fostering the culture of innovation in Nigerian Universities:** Institutions must foster a culture of innovation by involving all stakeholders in the planning and implementation of AI initiatives. Awareness campaigns, success stories, and demonstration projects can help demystify AI and highlight its benefits to staff and students alike. Creating a supportive environment where educators feel empowered, rather than threatened, by technology is essential. Providing incentives for early adopters, recognizing innovation in teaching and administration, and integrating digital literacy into staff evaluation criteria can promote wider acceptance and engagement. In the Nigerian context, universities must therefore reposition themselves from being passive consumers of imported technologies to becoming active participants in AI innovation networks. An AI-ready university should function as a knowledge hub where technology development, research, teaching, community engagement and entrepreneurship interact. Such an ecosystem enables institutions to develop solutions that reflect local realities rather than adopting technologies designed exclusively for different educational and cultural contexts. The National Information Technology Development Agency (NITDA) has equally played and still playing an important role in promoting digital innovation, cybersecurity awareness, and information technology development in Nigeria. Through indigenous EdTech Partnerships and Local Innovation the major limitation of technology adoption in developing countries of excessive dependence on imported solutions is reduced. Many educational technologies are designed according to assumptions about infrastructure availability, language, culture, assessment practices, and educational systems that may differ significantly from Nigerian

realities. An alternative approach involves developing partnerships with indigenous technology companies and local innovators. Through co-development models, universities can create AI solutions that address specific educational challenges. Rather than purchasing expensive foreign AI platforms requiring continuous subscription payments, universities can collaborate with Nigerian software developers to build context-sensitive AI tools adapted to local institutional needs. This approach supports technology sovereignty while strengthening Nigeria's educational technology sector.

7. **Provision of alternative energy solution/community engagement:** AI-ready universities must integrate alternative energy solutions such as: solar-powered microgrids; hybrid inverter systems; energy-efficient computing infrastructure. This approach represents a transition from electricity consumption to energy resilience. AI-ready universities should use their technological resources to support surrounding communities through knowledge transfer and capacity development. Faculties of Education, Computer Science, and Information Technology can collaborate to establish community AI literacy programmes targeting secondary school teachers; educational administrators; small businesses and community organizations.

Conclusion

The integration of Artificial Intelligence (AI) into higher education represents a transformative shift in the delivery, management, and experience of learning in the 21st century. For Nigeria, the adoption of AI offers a powerful tool for addressing many of the long-standing challenges in the higher education system, including overcrowded classrooms, administrative inefficiencies, low research output, and limited access to quality education. AI technologies such as smart tutoring systems, predictive analytics, virtual classrooms, and intelligent administrative tools have the potential to significantly improve teaching and learning outcomes, streamline university operations, and enhance the overall academic experience. To move forward, deliberate and coordinated efforts are required from all stakeholders, including government agencies, university management, academic staff, industry partners, and students. Investment in infrastructure, human capacity development, inclusive policymaking, and awareness campaigns must be prioritized to facilitate a smooth and sustainable integration of AI technologies into the educational ecosystem. While the road to AI adoption in Nigerian higher education may be challenging, it is both necessary and inevitable. Institutions that

embrace innovation and strategically position themselves to harness the power of AI will not only improve their educational delivery but will also become more competitive and relevant in the global knowledge economy. Therefore, the effective application of AI in Nigeria's higher education sector must be pursued with urgency, vision, and a commitment to excellence.

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Conference Papers

EFFECT OF INTERACTIVE WHITEBOARD PRESENTATION ON SENIOR SECONDARY SCHOOL STUDENTS' ACADEMIC ACHIEVEMENT IN COMPUTER STUDIES

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Abstract

This study examined the effect of interactive whiteboard (IWB) presentation on the achievement of senior secondary school students in computer studies in Ogun State, Nigeria. The study was guided by two research hypotheses. The study adopted a pre-test, post-test control group quasi-experimental design, using 152 senior secondary II (SS2) computer studies students from two purposively selected co-educational public schools. Participants were divided into experimental and control group, using two intact classes. A validated computer studies achievement test (CSAT) was administered to measure differences in academic achievements. Results revealed significant difference in achievement between the group taught computer with IWB and those taught with conventional group; with t-calculated value (1.97) greater than t-tabulated value (1.25) at 0.05 significant level. Results also showed no significant gender difference in students' achievement when taught computer studies with IWB, showing t-calculated values (1.09) less than t-tabulated value (1.99) at 0.05 significant level. Amongst other things, the study recommends provision of in-service training on IWB-based pedagogy for computer teachers.

Keywords: Academic Achievement, Virtual Reality, Augmented Reality, Interactive Whiteboards, Artificial Intelligence

Introduction

The inclusion of computer studies in Nigerian secondary school curriculum is highly essential in preparing students for a technology-driven world. This is in line with the government drive towards technology literacy among the youths. The increasing integration of technology across various sectors demands a workforce equipped with foundational knowledge of computing concepts and skills. Through computer studies, students are introduced to essential concepts such as basic programming, system operations, and data management, which are important for both academic and career pursuits. This foundational knowledge prepares students not only to use information and communication technology (ICT) effectively but also to contribute to national development (OECD, 2015). Undoubtedly, computer studies will immensely improve students' problem-solving, creativity, communication, collaboration, and critical thinking skills. Computer science improves students' ability to analyse problems, design computational solutions and ensuring they remain competitive in the global digital economy (Bukaliya, 2014; Lateef et al., 2024).

As the Nigerian government presses for technological integration in its socio-economic development, secondary education serves as a sub-structure for developing a skilled workforce capable of meeting the nation's technological needs. Schools act as a breeding place for training future software developers, information technology experts, and data managers who will drive technological transformation in various fields of human endeavor (Esharenana & Emperor, 2010;

Oladimeji et al., 2018). Additionally, computer literacy among young learners promotes digital citizenship, enabling them to use emerging technologies like artificial intelligence responsibly and ethically in their daily lives. This emphasis is in line with global trends supporting technology integration as a mainspring of education to reduce the technological gap (Amah & Amah, 2021). To achieve the above, the Nigerian Educational Research and Development Council (1998; 2004) made computer studies a core subject in secondary school.

In Nigeria, notwithstanding the importance attached to computer technology in the national curriculum, performance of secondary school students in computer studies has been a major concern for education stakeholders (Okekeokosisi & Okigbo, 2021). For instance, in 2021, 2022, 2023, and 2024 West African Examination Council Chief Examiners consistently reported that candidates' weaknesses were evident in the areas of computing terminologies, algorithms, web development, and basic programming. All this adversely determine the performance of the students and undermine the potential benefits of the subject. Obviously, this reflects broader issues in the education sector; including outdated curricula, lack of application of modern technology-enhanced methodologies by teachers and insufficient emphasis on the use of interactive, engaging, and collaborative educational technologies. Many students struggle to understand the core concepts of computer studies due to its abstract nature and the absence of hands-on-learning opportunities that are critical for mastery (Oladimeji et al., 2018). It should also be noted that as computer is a compulsory subject for students in arts, humanities and sciences the mathematical aspect of the subject makes it to be highly dreaded by students in Arts and Humanities, thereby contributing to the increasing number of students with poor performance.

Several factors contribute to students' poor performance in computer studies (Aebischer & Hilty, 2015; Abah, 2020). Traditional teaching methods used in Nigerian secondary schools are major barriers to effective learning of computers (Osijirin et al., 2025). These methods, often characterised by teacher-centered instruction, rely heavily on rote learning. While this approach may suffice for subjects that require theoretical knowledge, it is inappropriate for a skill-oriented subject like computer studies. Without opportunities to relate directly to computer systems, students will struggle to grasp abstract concepts, leading to low engagement and poor performance (Okekeokosisi et al., 2022); thus, active engagement of the student must be an essential feature of the instructional strategy employed for computer studies (Blah, 2021). For instance, topics such as algorithm development, basic programming, and web development require an experiential learning approach, which is often absent in traditional classroom settings. Other instructional strategies that may facilitate effective teaching of computer studies are project-based learning, hands-on labs, collaborative coding, computer assisted instruction, flipped classroom, gamification, learning management systems, real-world guest sessions, discussion, lecture-demo combo, continuous formative assessment, and problem-solving method.

Furthermore, instructional materials in most Nigerian schools are outdated and fail to reflect advancements in the field of ICT. Textbooks often contain obsolete information and lack concrete examples that provide students with the reality of experience (Chijioke et al., 2022). Additionally, many schools do not have adequate computer laboratories thereby forcing teachers to rely on conventional verbal explanations instead of interactive-driven technology which will enhance students' achievement. The absence of interactive learning resources further limits students' ability to engage actively with the subject matter. Consequently, students view computer studies as abstract, thereby reducing their motivation to excel in the subject. There are a number of traditional

and digital instructional media that can facilitate effective computer instruction such as pictorial charts, drawings, posters, models, TV, DVDs, resource persons, PowerPoint presentations, gamification, smartphones, internet, virtual reality, computer simulation, augmented reality, artificial intelligence, and interactive whiteboards. In order to facilitate highly engaging and interactive instructions for students' achievement, Cabus et al. (2017) and Anusiuba (2024) emphasised the use of the SMART board in instructional presentation, as this technology has empirically proven to have enhanced students' performance in various disciplines.

An interactive whiteboard (IWB) or SMART board is an advanced instructional technology tool designed to support interactive learning in modern classrooms. According to Bui (2023), a SMART board is a large, touch-sensitive board that is connected to a computer or projector, allowing teachers and students to interact directly or manipulate the digital content through touch or pen. A smartboard device typically includes software that enables annotation, saving of notes, and multimedia integration. Smart board assists teachers to develop dynamic instruction, which allows students to manipulate digital content like audio, texts, graphics, and video on the screen.

Wei et al. (2024) noted that the major components of a smartboard system include the whiteboard itself, a projector, a computer, and input tools such as pens or fingers. Some IWBs also display multi-touch capabilities, audio-visual outputs, and internet connectivity, which enhance interactivity and engagement during lessons (Wall et al., 2005). These boards can display any information shown on a computer screen, including websites, videos, documents, and educational software. In the classroom setting, the IWB serves as the focal point of instruction, enabling lively presentations, immediate feedback, and team learning. Teachers can use the IWB to explain intricate ideas using graphics, audio-visuals, animations, and simulations, particularly in subjects like computer studies, where abstract concepts need real illustration. Moreover, smartboard encourages students' active learning through drag-and-drop activities, quizzes, and other interactive exercises. These activities increase their enjoyment because they are physically involved through touching and manipulation of the content or images on the screen, which brings motivation and engagement. This underscores the idea of shifting from teacher-centered to student-centered pedagogical approaches, making lessons more engaging, hands-on activities, and effective (Hendawi & Nosair, 2020).

According to Wall et al. (2005), smartboard facilitates multisensory learning by integrating visual, auditory, and kinesthetic (VAK) elements into lessons. This is particularly important in a country like Nigeria, where classrooms can be crowded, whereas students' learning styles vary. With the use of IWB, teachers can present information in different formats: videos, diagrams, and even interactive games; thereby catering to different learning styles (Pierce, 2021). By engaging students in multiple ways, the smartboard will make lessons more entertaining, active, interesting, engaging, and motivating; thereby ensuring that no student is left behind in their learning process. In the context of computer studies, this is particularly important because many students struggle with the technical nature of the subject. The ability of the smartboard to break down complex topics into simpler, audio-visual formats can demystify topics like programming and data management, sparking interest and motivating the students to learn.

Empirically, several studies have directly investigated the impact of Smart boards on students' learning outcomes. A study by Karuppasamy and Lenin (2020) found a positive impact of smartboard use on improved test scores in various subjects, including mathematics and science. The researchers attributed these improvements to increased students' attention, enhanced

motivation, and better retention of complex materials due to the audio-visual and interactive nature of the presentation. Interactive Whiteboards have proven to be transformative tools in modern education, and several studies have confirmed the positive impact on students' learning. A study by Cabus et al. (2017) found that students taught mathematics with Smartboard significantly outperformed their counterparts taught through conventional method. Similarly, Hendawi and Nosair (2020) in a quasi-experimental study, reported that students exposed to social studies through a smartboard performed significantly better than students in the control group.

In a quasi-experimental study conducted by Nnyigide (2025), two groups of secondary school students were taught mathematics, one using traditional chalk-and-talk methods and the other using IWB-based instruction. The results showed the group exposed to IWB performed significantly better in post-tests, especially in topics that required conceptual understanding and problem-solving skills. In another study, Abumchukwu and Okeke (2020) examined the effect of IWB on secondary school students' achievement in chemistry. Findings showed that students taught using smartboard-enhanced lessons demonstrated improved understanding of chemistry compared to those in the control group. The study concludes that smartboard's ability to simulate activities contributed significantly to students' understanding. Contrarily, in another study, Al Halaibi and Thurston (2022) found no significant difference in the achievement of students exposed to mathematics through IWB and conventional teaching methods.

The moderating variable in the study is gender, in which studies have shown to have a significant impact on students' learning with technological devices. Studies revealed that gender stereotype beliefs have significantly influenced students' motivation and active engagement in learning activities. The influence of gender on learning with technology has been an inconclusive subject of debate among educational technology scholars. A quasi-experimental study by Oladejo et al. (2021) reported gender had no significant moderating effect on students' achievement in chemistry when taught with computer simulation. Xia et al. (2022) examined moderating effects of gender and need satisfaction on self-regulated learning through artificial intelligence, and findings revealed no significant effect of gender on students' attitude towards learning through artificial intelligence. Similarly, Stöhr et al. (2024) examined Perceptions and usage of AI chatbots among students in higher education across genders, academic levels, and fields of study and found no significant difference in the perception of male and female n the usage of ai chatbots. Contrarily, Elshaer et al. (2024) investigated the moderating effects of gender and study discipline in the relationship between university students' acceptance and use of ChatGPT and found significant effect of gender on students' acceptance and usage of ChatGPT. Findings revealed that majority of male students accepted and usage of ChatGPT compared to females. Findings of this study will contribute to ongoing discourse on gender related belief and stereotype over technology use by students. Also, Schweder and Raufelder (2021) examined needs satisfaction and motivation among adolescent boys and girls during self-directed learning intervention and findings show boys were significantly more satisfied and motivated with self-directed learning than girls.

Theoretical framework

This study is anchored on constructivist learning theory, which emphasises the active role of learners in constructing their own knowledge through experiences, thoughtfulness, and interplay with the environment (Piaget, 1972; Vygotsky, 1978). Rooted in cognitive psychology and developmental theories, constructivism challenges the traditional notion of passive learning by asserting that students do not just receive information but rather build understanding based on prior

knowledge and engagement with new experiences. Piaget's theory explains the importance of discovery-based learning (Rapanta, 2023). For instance, when teaching, a constructivist approach might involve students' virtual searching of software applications independently, experimenting with coding logic, or building simple programs through trial and error, thereby allowing them to construct their own understanding of difficult concepts rather than relying solely on teacher-based instruction.

According to Vygotsky (1978), learning is inherently social, and knowledge is co-constructed through collaboration with others. Effective learning takes place when learners receive scaffolding, temporary support structures that help them accomplish tasks beyond their current abilities (Peralta et al., 2023). As students become more proficient, the scaffolding is gradually removed, enabling them to perform independently. When applied to classroom instruction, particularly in technology-enhanced environments like those using Interactive Whiteboards, constructivist learning theory provides a strong foundation. IWBs facilitate interactivity, participatory and active learning, aligning well with both Piagetian and Vygotskian perspectives. For example, during a lesson on computer networking, students can collaboratively manipulate digital diagrams on the SMART boards, discuss network configurations, and solve problems together under the teacher's guidance, mirroring the social construction of knowledge emphasised by Vygotsky. Similarly, Piaget's emphasis on discovery learning can be supported through IWB activities that allow students to experiment with programming interfaces, simulate hardware setups, or explore software functions interactively. By combining interactivity with multimedia instruction, students are provided with rich, student-centered learning experiences that align with the demands of 21st century education.

Statement of the Problem

The academic performance of Nigerian secondary school students in computer studies remains unsatisfactory, as indicated by the WAEC Chief Examiner's reports. This performance is attributed to several systemic challenges; including gross use of outdated teaching methods, use of outdated instructional media, and lack of active students' engagement with emerging instructional technologies. Traditional teacher-centered instructional approaches dominate most classrooms, relying heavily on conventional and rote memorisation, which are inadequate for a subject that demands hands-on-experience and interactivity like computer studies. Despite the growing number of studies on instructional use of interactive whiteboard, there is less emphasis on its application in a developing classroom environment like Nigeria where access to digital tools are still evolving. Also, there is limited or no study investigating instructional application of IWB in computer instruction in Ogun State, specifically in secondary schools. This study addresses these gaps by focusing exclusively on the effect of IWB presentation on students' achievement in computer studies in Senior Secondary Two (SS2) Students in Ijebu Ode Local Government Area of Ogun State, Nigeria; thereby contributing to both local and global understandings of how technology-enhanced instruction can be optimised in diverse educational settings.

Research Hypotheses

$H0_1$: There is no significant difference in achievement between students taught computer studies through interactive whiteboard presentation and those taught with traditional method.

$H0_2$: There is no significant gender difference in achievement between students taught computer studies through interactive whiteboard presentation.

Methodology

Research Design

This study adopts a pretest-posttest, control group, quasi-experimental research design within a 2 x 2 factorial matrix. The matrix comprises two treatment conditions (interactive whiteboard presentations and traditional lecture method) and gender as a moderating variable at two levels (male and female).

Population of the Study

The population for this study comprised all Senior Secondary Two (SS2) Students in co-educational public secondary schools within Ijebu Ode Local Government Area of Ogun State, Nigeria.

Sample and Sampling Technique

One hundred and fifty-two (152) students constitute the sample size. Two co-educational public secondary schools that were distantly located were purposively selected in the Ijebu-Ode. One school was assigned to the experimental group, while the other was assigned to the control group. To avoid disrupting the natural classroom setting, one intact SS 2 class was purposively selected in each school, making two intact classes.

Instrumentation

Instructional Guide for the Interactive Whiteboard (IGIWB)

To ensure instructional fidelity and standardization during the treatment period, an instructional guide was meticulously designed by the researchers for the experimental group. The guide structured the lessons around specific behavioral objectives, targeted educational media, core computer science content, structured teacher activities, active student activities, and continuous formative evaluation. The primary medium utilized was the Interactive Whiteboard (IWB), which integrated multimedia elements such as educational videos and animations used to visually break down abstract computing operations. The interactive presentation is designed to promote collaborative, hands-on learning. Rather than remaining passive observers, students were actively called upon to physically interact with and manipulate the digital content directly on the smartboard screen, fostering higher-order cognitive competencies (knowledge, comprehension, and application). To ensure its pedagogical and structural soundness, the draft instructional guide was subjected to face and content validation by a panel of experts in Educational Technology and Computer Science. Their feedback and recommendations were integrated into the final blueprint used by the trained research assistant.

Computer Studies Achievement Test (CSAT)

The Computer Studies Achievement Test (CSAT) was developed by the researchers as the primary instrument to measure the dependent variable (academic achievement). The test was strictly based on the specific content areas outlined in the Nigerian National Curriculum for Senior Secondary II (SS2) Computer Studies. Format: The final instrument is a 50-item, multiple-choice objective test with four options (A–D) and a single correct answer. Initially, a pool of 80 objective test items was

drafted by the researchers and reviewed by subject-matter experts to verify clarity, contextual relevance, and alignment with instructional goals. The initial 80 items were psychometrically tested via an item analysis phase. Thirty (30) items that failed to meet standard difficulty or discrimination indices were discarded, leaving 50 highly discriminative items for the final instrument. To establish the internal consistency and stability of the CSAT over time, the instrument was pilot-tested on an intact class of twenty (20) SS2 computer studies students. These students belonged to a public co-educational secondary school within the state that shared identical characteristics with the study sample but was completely excluded from the main experiment. The resulting pilot test scores were analyzed using the Kuder-Richardson Formula 20 (KR-20). The calculation yielded a high reliability coefficient of 0.86. In educational research, a KR-20 coefficient above 0.70 is considered highly reliable, confirming that the CSAT possessed excellent internal consistency and stability for measuring student achievement.

Method of Data Collection

The process of data collection was carried out in four phases: training of the research assistant in the experimental group, pre-test, treatment, and post-test.

Table1: Summary of Procedure for Data Collection

Week	Activity	Experimental Group	Conventional Group
WK1	Training of Research Assistant	Research assistant (the computer teacher) was trained on IWB operation, multimedia integration, and lesson delivery procedures. The instructional package on computer studies was saved on the IWB.	No training provided, teacher was asked to teach in a normal chalk and talk method.
WK2	Pre-Test Administration	Computer Studies Achievement Test (CSAT) administered	Computer Studies Achievement Test (CSAT) administered
WK3	Week 1 of Intervention	Topic: Program Development I - Definition, Characteristics of a good program development.	Program Development I covered through conventional method
WK4	Week 2 of Intervention	Topic: Program Development II - hands-on practice with IWB-based simulations	Program Development II chalk-and-talk illustrations.
WK5	Week 3 of Intervention	Topic: Algorithms and flow chart - Types of algorithms - Students worked in groups on the IWB to create and test flowcharts in real-time.	Algorithms and flow chart covered using traditional lecture method.
WK6	Week 4 of Intervention	Topic: Internet and Communication I - Interactive videos, live web demos, and virtual tours of network structures via IWB	Taught using chalk- and talk method.
WK7	Week 5 of Intervention	Topic: Internet and Communication II - Network types – Engaging videos and live simulations were shown on the IWB to help students visualize network setups.	Taught using traditional chalk and talk method.
WK8	Week 6 of Intervention	Topic: Electronic Mail - Understanding email components and workflow – Creating and managing email accounts in real-life scenarios.	Electronic mail taught through chalk and talk method.
WK9	Post-Test Administration	CSAT re-administered under similar condition as pre-test	CSAT re-administered under similar condition as pre-test

Method of Data Analysis

An independent sample t-test was applied to differentiate achievement of students in both the experimental and control groups, as well as the moderating effect of gender.

Results

Table 2: T-test showing a significant difference in achievement between students taught computer studies with an interactive whiteboard and those treated with the traditional method.

Groups	N	Mean	SD	Df	t-cal	t-tab	Decision
Experimental	70	31.60	8.02	150	1.97	1.25	Reject hypothesis
Control	82	19.38	7.98				

@0.05 significant level

Table 2 shows that calculated value of *t* (1.97) is higher than the tabulated value of (1.25), with a degree of freedom of (150) at a 0.05 level of significance. This suggests a significant difference in achievement between the groups; thus, the null hypothesis is rejected. The mean shows that students in the IWB group performed better than the control group.

Table 3: T-test comparing achievement between male and female students taught computer studies with an interactive whiteboard.

Groups	N	Mean	SD	Df	t-cal	t-tab	Decision
Male	27	31.38	8.26	68	1.09	1.99	Fail to reject
Female	43	31.20	8.12				

@0.05 significant level

Table 3 showed that the calculated value of *t* (1.09) is less than the tabulated value (1.99), with degrees of freedom (68) at a 0.05 level of significance. This indicates no significant difference in achievement between the two groups; thus, the null hypothesis is accepted. The mean value shows almost equal performance by gender, meaning that gender has no significant influence on the performance of students in IWB classroom.

Discussion of Findings

The findings of this study regarding the first hypothesis demonstrated a statistically significant difference between the academic achievement of students taught computer studies using Interactive Whiteboard (IWB) presentations and those taught via conventional methods. Specifically, students in the IWB experimental group achieved significantly higher post-test scores than their counterparts in the control group. This outcome strongly corroborates previous empirical literature highlighting the transformative nature of smartboard technologies. For instance, the findings align with Hendawi and Nosair (2020), whose quasi-experimental study reported that students exposed to social studies lessons via smartboards significantly outperformed the control group. Similarly, Abumchukwu and Okeke (2020) observed that smartboard-enhanced lessons yielded a vastly superior conceptual understanding of chemistry. More recently, Nnyigide (2025) demonstrated that IWB-based instruction significantly boosts post-test performance, particularly

in complex topics requiring robust problem-solving skills and abstract conceptual clarity. The clear pedagogical implication here is that the structural attributes of the SMART Board: namely its real-time interactivity, multi-sensory engagement, collaborative interface, and capacity for hands-on manipulation successfully shift the classroom dynamic away from passive learning. In a technical subject like computer studies, these features demystify abstract algorithms and computing processes, driving active learner-centered comprehension that directly manifests as superior academic performance.

The results of the second hypothesis revealed that gender did not exert a statistically significant moderating effect on the academic achievement of secondary school students when exposed to computer studies through IWB-based instruction. Both male and female students within the experimental group benefited equally from the technology, showing no disparate variations in their performance. This finding adds vital evidence to the ongoing global discourse on gender and educational technology, reinforcing the premise that well-designed, technology-rich environments are inherently inclusive. This outcome directly mirrors the findings of Oladejo et al. (2021), who noted that gender had no significant moderating influence on chemistry achievement when students were taught using computer simulations. It further aligns with Xia et al. (2022), whose exploration into artificial intelligence-driven self-regulated learning revealed no significant gendered differences regarding student attitudes. Furthermore, Stöhr et al. (2024) confirmed that perceptions and operational usage of emergent digital tools, such as AI chatbots, remain balanced across male and female lines in higher education.

Ultimately, these results underscore a powerful educational truth: when an instructional medium is sufficiently engaging, multisensory, and hands-on, traditional gender-based gaps or technological stereotypes in STEM subjects are effectively minimized. The Interactive Whiteboard serves as an equitable, gender-neutral pedagogical tool capable of motivating all learners uniformly.

Conclusion

This study investigated the effect of Interactive Whiteboard (IWB) presentation on the academic achievement of senior secondary school computer studies students in Ogun State, Nigeria, while examining the moderating role of gender. Based on the empirical evidence obtained, it is concluded that IWB-based instruction is a highly effective pedagogical approach for teaching computer studies. Technology vastly outperforms conventional, teacher-centered lecture methods by transforming abstract computing concepts into tangible, interactive, and visually stimulating lessons. Furthermore, this study concludes that the academic benefits of the SMART board are equitable and universal across genders. The lack of a significant difference between male and female post-test scores underscores the gender-neutral effectiveness of IWB presentations, proving that interactive educational technologies can effectively mitigate traditional gender disparities in STEM-related subjects.

Recommendations

Since the study revealed the instructional efficacy of smartboards, teachers and curriculum designers should incorporate technology into the teaching of computer studies to enhance students' academic achievement and active engagement. Nigerian schools should organise workshops and training for computer studies' teachers on how to effectively utilise interactive whiteboard technology in the classroom for improved teaching effectiveness and to maximise the pedagogical

potential of the educational technology. Since interactive whiteboards are found to be effective for both male and female students, educators should adopt such inclusive technology that supports equal learning opportunities for all genders; so that no one is left behind. Government, schools, and education stakeholders should invest in the provision and utilisation of Interactive Whiteboard facilities to support interactive and learner-centered computer instruction.

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LEARNING EXPERIENCE DESIGN IN ARTIFICIAL INTELLIGENCE-SUPPORTED BIOLOGY CLASSROOMS: IMPLICATIONS FOR STUDENT MOTIVATION AND ACADEMIC PERFORMANCE

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Abstract

The rapid emergence of Artificial Intelligence (AI) in education has introduced new possibilities for transforming teaching and learning processes, particularly within science education contexts. However, the educational value of AI is not determined solely by the availability of advanced technologies but by the quality of learning experiences created around their use. This position paper examines Learning Experience Design (LXD) as a critical framework for effective integration of Artificial Intelligence into biology classrooms and explores its implications for students' motivation and academic performance. The paper argues that AI-supported biology instruction should move beyond technology-driven approaches toward intentional learner-centred design that promotes engagement, personalization, interaction, and meaningful knowledge construction. Through the application of LXD principles such as adaptive learning, immediate feedback, active participation, collaborative learning, and contextualized instruction, AI tools can support deeper understanding of biological concepts that are often abstract and difficult for learners. The paper highlights that AI-supported learning environments have the potential to improve student motivation by enhancing learner autonomy, confidence, curiosity, and academic engagement. Furthermore, AI applications such as intelligent tutoring systems, virtual laboratories, automated assessment platforms, and adaptive learning technologies can contribute to improved academic performance by providing personalized learning pathways and timely instructional support. Despite these opportunities, challenges including digital inequality, teacher preparedness, ethical concerns, and overdependence on technology require careful consideration. The paper concludes that Learning Experience Design provides a sustainable pathway for maximizing the benefits of Artificial Intelligence in biology education by ensuring that technology serves pedagogical goals rather than replacing human instructional expertise.

Keywords: Learning Experience Design, Artificial Intelligence, Biology Education, Student Motivation, Academic Performance, AI-Supported Learning, Position Paper

Introduction

The 21st-century educational landscape is undergoing significant transformation due to rapid technological advancement, increasing digital innovation, and changing expectations of learners. Among the emerging technologies influencing education, Artificial Intelligence (AI) has become

one of the most influential tools capable of reshaping teaching and learning practices (Holmes, Bialik, & Fadel, 2019; UNESCO, 2021). Artificial Intelligence refers to computer-based systems designed to perform tasks that traditionally require human intelligence, including learning, reasoning, decision-making, problem-solving, language processing, and pattern recognition (Russell & Norvig, 2021). In education, AI has created opportunities for personalized instruction, automated assessment, intelligent tutoring, learning analytics, and adaptive learning environments (Zawacki-Richter et al., 2019; Chen, Chen, & Lin, 2020). These developments have generated new possibilities for improving instructional effectiveness and addressing individual differences among learners (Luckin et al., 2016). However, despite the increasing adoption of AI tools in education, concerns remain regarding whether these technologies genuinely improve learning outcomes or merely introduce new forms of digital content delivery (Selwyn, 2019; UNESCO, 2021). Biology education presents a unique context where AI integration can provide meaningful benefits. Biology involves complex concepts such as cellular processes, genetics, ecology, evolution, anatomy, and physiological systems. Many biological concepts are abstract and difficult for students to understand through conventional instructional approaches alone (Michael, 2007; Orgill, 2012). Traditional biology teaching methods may sometimes limit learners' opportunities for visualization, experimentation, inquiry, and practical engagement (National Research Council, 2012).

Artificial Intelligence-supported learning environments provide opportunities to overcome these limitations through interactive simulations, virtual laboratories, intelligent feedback systems, and adaptive instructional resources (Chen et al., 2020; Zawacki-Richter et al., 2019). For instance, students can explore biological processes through virtual models, receive immediate feedback on assessments, and engage with learning materials designed according to their individual learning needs (Holmes et al., 2019). However, the effectiveness of AI in biology classrooms depends largely on how learning experiences are designed. The presence of technology alone does not guarantee improved motivation or academic achievement (Selwyn, 2019). Poorly designed AI applications may result in passive learning, reduced critical thinking, and overdependence on automated systems (Williamson & Eynon, 2020). Therefore, there is a need to shift attention from technology adoption to Learning Experience Design (LXD), which focuses on creating meaningful, engaging, and learner-centred educational experiences (Tannenbaum, 2018). Learning Experience Design emphasizes the deliberate planning of interactions between learners, content, instructors, and learning technologies to achieve desired educational outcomes **(**Woolf, 2010**)**. In AI-supported biology classrooms, LXD provides a framework for ensuring that artificial intelligence tools are aligned with students' cognitive, emotional, and motivational needs **(**Dirksen, 2016**).**

Statement of the Problem

The integration of Artificial Intelligence (AI) into education has created new opportunities for improving teaching and learning processes, especially in science education. However, the increasing availability of AI-driven educational tools does not automatically translate into improved learning outcomes. In many biology classrooms, the use of emerging technologies often focuses more on the adoption of digital tools rather than on the design of meaningful, engaging, and learner-centred learning experiences. This creates a gap between technological innovation and effective instructional practice. Biology as a subject contains many abstract and complex concepts,

including cellular processes, genetics, ecology, evolution, anatomy, and physiological systems, which students often find difficult to understand through conventional teaching methods. Although AI-supported tools such as intelligent tutoring systems, virtual laboratories, adaptive learning platforms, and automated feedback systems have the potential to improve visualization, interaction, and personalization of learning, their effectiveness depends on how these technologies are pedagogically designed and implemented.

Furthermore, poorly structured AI-supported learning environments may result in passive learning, reduced learner engagement, overdependence on technology, and limited development of critical thinking skills. There is therefore a need to move beyond technology-driven approaches and focus on Learning Experience Design (LXD), which emphasizes the intentional creation of interactive, meaningful, and learner-focused educational experiences. Despite the growing interest in AI applications in education, limited attention has been given to how Learning Experience Design principles can guide AI integration in biology classrooms to enhance students' motivation and academic performance. This gap raises concerns about how AI can be effectively utilized to support deeper understanding, active participation, learner autonomy, and improved achievement in biology learning. Hence, this study examines the role of Learning Experience Design in AI-supported biology classrooms and its implications for students' motivation and academic performance.

Purpose of the Study

The purpose of this study is to examine the role of Learning Experience Design in Artificial Intelligence-supported Biology classrooms and explore its implications for improving students' motivation and academic performance.

Specifically, the study aims to:

1. Examine how Learning Experience Design principles can enhance the effectiveness of Artificial Intelligence integration in biology classrooms.
2. Explore the influence of AI-supported learning experiences designed through LXD principles on students' motivation, engagement, confidence, and interest in biology.
3. Determine how AI-supported learning environments contribute to students' academic performance in biology through personalization, feedback, interaction, and adaptive learning.
4. Identify the challenges associated with implementing Learning Experience Design approaches in AI-supported biology instruction, including issues related to teacher preparedness, digital inequality, ethical concerns, and technology dependence.
5. Propose a learner-centred framework for effective integration of Artificial Intelligence in biology education through Learning Experience Design.

Literature Review

Artificial Intelligence in Education and Emerging Trends in Learning

The rapid advancement of digital technologies has significantly transformed educational practices in the 21st century. Among these emerging technologies, Artificial Intelligence (AI) has gained considerable attention due to its ability to simulate human intelligence processes such as reasoning, problem-solving, decision-making, language processing, and learning. Artificial Intelligence in education refers to the application of intelligent computer-based systems to support teaching, learning, assessment, and educational management processes (Russell & Norvig, 2021).

AI has increasingly influenced educational environments by providing opportunities for personalized learning, automated assessment, intelligent tutoring systems, adaptive learning platforms, and learning analytics. These applications enable educational systems to respond to individual learners' needs by analyzing learning behaviours, identifying knowledge gaps, and providing targeted instructional support (Zawacki-Richter et al., 2019; Chen, Chen, & Lin, 2020). According to Holmes, Bialik, and Fadel (2019), AI has the potential to transform education by improving learner engagement, supporting teachers' instructional decisions, and creating more flexible learning experiences. The integration of AI into education has also shifted attention from traditional teacher-centred approaches toward more personalized and learner-centred learning environments. AI-supported systems can provide learners with immediate feedback, adaptive learning pathways, and interactive resources that promote active engagement and independent learning (Luckin et al., 2016). However, the presence of AI technologies alone does not guarantee improved learning outcomes. Selwyn (2019) argues that educational technology must be evaluated based on the quality of learning experiences created rather than simply the availability of technological tools. Therefore, effective AI integration requires careful consideration of pedagogy, learner needs, and instructional design principles.

Artificial Intelligence in Biology Education

Biology provides an important context for the application of Artificial Intelligence due to the complexity and abstract nature of many biological concepts. Biology involves the study of processes and systems such as cellular activities, genetics, evolution, ecology, anatomy, and physiology, which often require learners to develop conceptual understanding through visualization, experimentation, and inquiry-based learning. Many students experience difficulties understanding biological phenomena because they involve processes that cannot always be directly observed in conventional classroom settings (Michael, 2007; Orgill, 2012).

Traditional approaches to biology instruction may sometimes limit students' opportunities for interactive exploration and practical engagement. According to the National Research Council (2012), effective science learning requires opportunities for learners to engage in scientific practices, construct explanations, and apply knowledge to real-world contexts. AI-supported learning environments provide possibilities for addressing these challenges through virtual laboratories, simulations, intelligent tutoring systems, and adaptive learning resources (Chen et al., 2020). Through AI applications, biology learners can explore complex biological processes using digital models and simulations, receive immediate feedback on their understanding, and access learning materials that match their individual abilities and learning pace (Holmes et al., 2019). For

example, virtual laboratory environments can provide opportunities for experimentation where physical resources may be limited, while AI-based assessment systems can identify areas of difficulty and provide personalized instructional support (Zawacki-Richter et al., 2019). Despite these benefits, AI integration in biology classrooms requires careful planning. Poorly designed AI applications may encourage passive consumption of information, reduce learners' critical thinking abilities, and create excessive dependence on automated systems (Williamson & Eynon, 2020). Therefore, attention must shift from simply adopting AI tools toward designing meaningful learning experiences that promote active participation, inquiry, and deeper understanding.

Learning Experience Design and AI-Supported Learning

Learning Experience Design (LXD) provides an important framework for ensuring that educational technologies such as Artificial Intelligence are effectively aligned with learning objectives. Unlike technology-driven approaches that focus mainly on introducing digital tools, LXD emphasizes the intentional design of interactions among learners, instructors, content, and technology to create engaging and meaningful learning experiences (Dirksen, 2016).

Learning Experience Design is concerned with understanding learners' cognitive, emotional, and motivational needs and using this understanding to develop learning environments that encourage participation and knowledge construction. Woolf (2010) explains that effective technology-supported learning requires learner-centred strategies that consider how students process information, receive feedback, and develop understanding.

In AI-supported biology classrooms, LXD ensures that AI tools function as supportive learning resources rather than replacements for teachers. Through LXD principles such as personalization, active engagement, collaboration, contextual learning, and continuous feedback, AI can support improved learning experiences. This approach allows learners to interact with biological concepts through meaningful activities rather than merely receiving information. Furthermore, LXD contributes to improved motivation by promoting learner autonomy, confidence, curiosity, and active involvement. When AI systems are designed around learners' needs, students are more likely to participate actively and develop positive attitudes toward learning (Luckin et al., 2016). Consequently, the combination of AI and LXD has the potential to enhance academic performance by supporting individualized instruction and addressing learners' differences.

AI-Supported Learning, Student Motivation, and Academic Performance

Student motivation plays a critical role in determining learning success. Learners who are motivated are more likely to participate actively, persist in challenging tasks, and develop deeper understanding. AI-supported learning environments can influence motivation by providing immediate feedback, personalized learning experiences, and opportunities for self-directed learning (Holmes et al., 2019). In biology education, AI-based tools may increase students' interest and confidence by making difficult concepts more interactive and understandable. Adaptive learning systems can adjust instructional content based on learners' progress, thereby reducing frustration and improving engagement (Chen et al., 2020). Similarly, intelligent tutoring systems can provide individualized support that may enhance students' achievement and conceptual understanding. However, the impact of AI on academic performance depends on the quality of

instructional design. Technology without appropriate pedagogical integration may not produce meaningful improvements in learning outcomes (Selwyn, 2019). Therefore, Learning Experience Design becomes essential in ensuring that AI applications promote active learning, critical thinking, and meaningful knowledge construction.

Challenges of AI Integration in Biology Education

Although AI offers significant opportunities for improving education, several challenges must be considered. One major concern is unequal access to digital infrastructure, which may create differences between learners who have access to AI-supported learning environments and those who do not (UNESCO, 2021). Other challenges include teachers' preparedness, ethical concerns, data privacy issues, and the possibility of excessive reliance on automated systems. Teachers require adequate knowledge and skills to effectively integrate AI tools into classroom practice. Without proper training, AI applications may be used superficially without achieving their intended educational benefits (Zawacki-Richter et al., 2019). Ethical issues related to learner data, transparency of AI decisions, and responsible technology use also require attention (UNESCO, 2021). Therefore, sustainable AI integration in biology education requires a balanced approach where technology supports, rather than replaces, human instructional expertise. Learning Experience Design provides a useful pathway for achieving this balance by ensuring that AI applications remain focused on improving learner engagement, motivation, and academic achievement.

Contextual and Experiential Learning in AI-Supported Biology Classrooms

Learning becomes more meaningful and effective when learners are able to connect theoretical knowledge with real-life experiences and practical situations. Contextual and experiential learning emphasizes the active involvement of learners in constructing knowledge through interaction with authentic environments, problem-solving activities, and real-world applications. In biology education, this approach is particularly important because many biological concepts require learners to understand relationships between organisms, environmental factors, and human activities. Artificial Intelligence-supported Learning Experience Design (LXD) provides opportunities for integrating contextual and experiential learning into biology classrooms through interactive simulations, virtual environments, and problem-based learning activities. AI technologies can create realistic learning experiences where students explore environmental challenges, health-related situations, and ecological problems. For example, AI-driven environmental models can enable learners to examine the impact of climate change on ecosystems, analyze population changes, and explore possible conservation strategies. Such experiences promote deeper understanding by allowing students to apply biological knowledge beyond classroom explanations (Holmes, Bialik, & Fadel, 2019; Chen, Chen, & Lin, 2020). Through effective Learning Experience Design, AI-supported activities can move biology learning from passive information reception toward active knowledge construction. Learners become involved in investigation, decision-making, and scientific reasoning, thereby improving their ability to apply biological principles to real-world situations (Luckin et al., 2016).

Implications of AI-Supported Learning Experience Design for Student Motivation

Student motivation is an essential factor influencing learning engagement, persistence, and achievement. Motivated learners are more likely to participate actively, demonstrate curiosity, and develop deeper understanding of learning content. AI-supported Learning Experience Design can enhance student motivation by creating personalized, interactive, and learner-centred environments that respond to individual differences (Zawacki-Richter et al., 2019).

Increased Learner Engagement

AI-supported learning environments can increase learner engagement by providing interactive and dynamic experiences that capture students' attention. Unlike traditional lecture-based approaches that may limit active participation, AI applications encourage learners to explore concepts, ask questions, solve problems, and participate in meaningful activities. Interactive simulations, intelligent tutoring systems, and adaptive learning platforms provide opportunities for students to engage directly with biological concepts rather than simply memorize information (Chen et al., 2020). Increased engagement can strengthen learners' interest in biology and promote positive attitudes toward science learning.

Improved Self-Efficacy

Self-efficacy refers to learners' confidence in their ability to successfully perform learning tasks. Students who believe they can succeed are more likely to persist when faced with challenging concepts. AI-supported learning environments can improve self-efficacy by providing individualized support, gradual learning progression, continuous feedback, and instructional guidance based on learners' needs (Holmes et al., 2019). In Biology classrooms, where students often encounter difficult concepts such as genetics, cellular processes, and physiological mechanisms, personalized AI support can help learners overcome misconceptions and develop confidence in their abilities. Immediate feedback also enables students to recognize their progress and make necessary improvements.

Promotion of Learner Autonomy

AI-supported Learning Experience Design promotes learner autonomy by allowing students to take greater responsibility for their learning process. Through adaptive learning systems, students can review difficult concepts, access additional learning resources, and progress according to their preferred learning pace (Luckin et al., 2016). This independence encourages self-directed learning and supports the development of lifelong learning skills. Rather than depending entirely on the teacher, learners become active participants who make decisions about their learning activities.

Increased Curiosity and Interest

Biology involves the exploration of living organisms and natural processes. However, some biological phenomena are difficult to observe directly in classroom settings. AI-supported tools such as virtual organisms, simulations, and intelligent learning assistants can make invisible biological processes more observable and interactive. By presenting biological concepts in

engaging formats, AI can stimulate curiosity and encourage learners to explore scientific ideas beyond classroom instruction (Michael, 2007; Orgill, 2012). This increased curiosity contributes to stronger motivation and sustained interest in biology learning.

Implications of AI-Supported Learning Experience Design for Academic Performance

Academic performance reflects learners' ability to acquire knowledge, demonstrate understanding, apply concepts, and develop relevant skills. In biology education, academic achievement depends largely on students' ability to understand abstract concepts, interpret scientific information, and apply biological principles to practical situations. AI-supported Learning Experience Design has significant potential to improve academic performance by providing personalized instruction, interactive learning opportunities, and continuous instructional support (Zawacki-Richter et al., 2019).

Improved Conceptual Understanding

Many biological concepts involve processes that cannot be easily observed directly. Topics such as cell division, genetic inheritance, ecological relationships, and physiological systems often require visualization and explanation beyond conventional textbooks. AI-supported learning environments improve conceptual understanding through animated explanations, three-dimensional models, interactive simulations, and virtual experiments. These tools allow students to observe biological processes step-by-step and develop clearer mental models of complex concepts (Chen et al., 2020). Through effective LXD, AI technologies transform abstract biological ideas into meaningful learning experiences that support deeper understanding and knowledge retention.

Enhanced Problem-Solving and Critical Thinking Skills

Modern biology education emphasizes scientific inquiry, analysis, and problem-solving rather than memorization alone. AI-supported learning environments can promote higher-order thinking by presenting learners with scientific problems, real-life biological scenarios, research activities, and data interpretation tasks. Students can analyze information, generate explanations, make predictions, and propose solutions to biological challenges. For example, AI-supported ecological simulations can require learners to investigate environmental changes and develop strategies for biodiversity conservation. Such activities encourage scientific reasoning and critical thinking skills (National Research Council, 2012).

Improved Knowledge Retention

Learning retention improves when students actively interact with learning materials and receive opportunities for practice and feedback. AI-supported LXD enhances retention through personalized revision activities, repeated learning opportunities, interactive experiences, and immediate corrective feedback (Holmes et al., 2019). Rather than focusing only on short-term examination preparation, learners develop meaningful understanding that can be transferred to new situations.

Support for Practical Biology Skills

Practical activities are central to biology education because they allow learners to develop scientific skills and connect theory with observation. However, many schools experience challenges such as limited laboratory facilities, inadequate equipment, and insufficient practical exposure. AI-supported virtual laboratories provide additional opportunities for learners to conduct simulated experiments, observe biological structures, practice scientific procedures, and explore experimental outcomes safely (Woolf, 2010). Although virtual laboratories cannot completely replace physical laboratory experiences, they serve as valuable complementary tools.

Differentiated Learning for Diverse Learners

Learners differ in their abilities, prior knowledge, learning speed, and preferred learning approaches. AI-supported LXD promotes differentiated learning by adapting instructional content to individual learner needs. AI systems can provide additional support for struggling learners, advanced activities for high-performing students, and multiple ways of presenting information (Zawacki-Richter et al., 2019). This inclusive approach ensures that students receive learning experiences suitable for their abilities.

Challenges of AI-Supported Learning Experience Design in Biology Classrooms

Despite the potential benefits of AI-supported learning, several challenges may affect successful implementation in biology classrooms.

Digital Divide and Access Limitations

Effective AI integration depends on access to digital devices, internet connectivity, electricity, and appropriate learning platforms. Learners in resource-limited environments may have unequal access to AI-supported educational opportunities, thereby creating differences in learning experiences (UNESCO, 2021). Educational institutions must therefore develop strategies that promote equitable access and ensure that technological advancement does not increase educational inequality.

Teacher Preparedness and Digital Competence

Teachers remain central to successful AI integration. Although AI tools provide instructional support, teachers require adequate knowledge and skills to select, implement, and evaluate AI-based learning resources. Some teachers may experience difficulties in using AI tools, designing AI-supported lessons, evaluating AI-generated information, and managing technology-enhanced classrooms (Zawacki-Richter et al., 2019). Continuous professional development is therefore necessary to prepare biology teachers for effective AI implementation.

Ethical Issues and Data Privacy

AI systems often collect and analyze learner data to personalize educational experiences. However, this raises concerns regarding student privacy, data security, and responsible use of learner

information (UNESCO, 2021). Educational institutions must establish ethical guidelines that ensure transparency, accountability, and responsible use of AI technologies.

Overdependence on Technology

Although AI provides valuable instructional support, excessive dependence on technology may negatively affect creativity, independent thinking, and teacher–student interaction. AI should function as a supportive tool rather than replace human teaching expertise (Selwyn, 2019). The teacher remains essential in providing guidance, motivation, emotional support, and scientific mentorship.

Accuracy and Reliability of AI Information

AI systems may sometimes produce inaccurate, incomplete, or misleading information. In biology education, incorrect explanations can result in scientific misconceptions. Therefore, learners and teachers must critically evaluate AI-generated content and compare information with reliable scientific sources (Williamson & Eynon, 2020). Effective AI-supported biology education requires a balanced approach where technology enhances, rather than replaces, sound pedagogical practices.

Recommendations

Based on the discussion, the following recommendations are proposed:

1. Biology teachers should integrate AI tools using Learning Experience Design principles rather than adopting technology without clear instructional objectives.
2. Teacher training programmes should include AI literacy and digital pedagogy to improve educators' competence in AI-supported classrooms.
3. Educational institutions should provide adequate digital infrastructure to ensure equitable access to AI-supported learning opportunities.
4. AI applications should be designed around learner needs, focusing on engagement, feedback, personalization, and active participation.
5. Schools should combine AI-supported learning with traditional practical activities to maintain hands-on scientific experiences.
6. Clear ethical guidelines should be developed to address data privacy, responsible AI use, and academic integrity.
7. Further research should examine the long-term effects of AI-supported LXD on biology achievement, motivation, and scientific skills.

Conclusion

Artificial Intelligence has the potential to transform biology education by creating more interactive, personalized, and engaging learning environments. However, the effectiveness of AI in classrooms does not depend simply on the presence of advanced technologies but on how learning experiences are intentionally designed.

Learning Experience Design provides an important framework for ensuring that AI tools support meaningful learning by addressing learners' cognitive, emotional, and motivational needs. Through personalization, immediate feedback, interactive simulations, and contextual learning, AI-supported biology classrooms can enhance student motivation and improve academic performance.

Nevertheless, successful implementation requires attention to challenges such as digital inequality, teacher preparedness, ethical concerns, and responsible technology use. The future of AI in biology education should therefore focus on a balanced approach where technology enhances human teaching rather than replaces it. By placing Learning Experience Design at the centre of AI integration, biology classrooms can become more inclusive, engaging, and effective environments for 21st-century learners.

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EVALUATING THE INFLUENCE OF INSTITUTIONAL INFRASTRUCTURE AND GOVERNMENT POLICIES ON ARTIFICIAL INTELLIGENCE ADOPTION IN EDUCATIONAL INSTITUTIONS IN KOGI STATE, NIGERIA

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Abstract

This study evaluated the influence of institutional infrastructure and government policies on artificial intelligence adoption in educational institutions in Kogi State, Nigeria. The study was motivated by the growing importance of artificial intelligence in enhancing teaching, learning, research, and administrative efficiency in educational institutions, alongside the persistent challenges affecting its adoption in many Nigerian schools. Two research questions and two hypotheses guided the study. The study adopted a descriptive survey research design. The population of the study comprised 4,862 academic staff and ICT personnel from selected public tertiary institutions in Kogi State. A sample size of 370 respondents was obtained using Taro Yamane's formula and selected through multistage sampling procedure. Data were collected using a structured questionnaire titled *Institutional Infrastructure, Government Policies and Artificial Intelligence Adoption Questionnaire (IIGPAIAQ).* The instrument was validated by experts and tested for reliability using Cronbach Alpha, which yielded an overall reliability coefficient of 0.84. Mean and standard deviation were used to answer the research questions, while Pearson Product Moment Correlation (PPMC) was used to test the hypotheses at 0.05 level of significance. The findings revealed that institutional infrastructure significantly influences artificial intelligence adoption in educational institutions in Kogi State. The study also found a very strong positive and significant relationship between government policies and artificial intelligence adoption. The hypotheses tested showed significant relationships between institutional infrastructure and AI adoption ($r = 0.824$, $p < 0.05$), and between government policies and AI adoption ($r = 0.912$, $p < 0.05$). The study concluded that adequate infrastructural facilities and supportive government policies are essential for effective artificial intelligence adoption in educational institutions. The study recommended improved ICT infrastructure, stable electricity supply, adequate funding, and effective policy implementation to enhance sustainable AI integration in education.

Keywords: Artificial Intelligence, Institutional Infrastructure, Government Policies, Educational Institutions

Introduction

Artificial intelligence (AI) has emerged as one of the most transformative technological innovations influencing education systems globally. Educational institutions across the world are increasingly integrating AI-driven technologies such as intelligent tutoring systems, automated assessment platforms, predictive analytics, virtual learning assistants, and adaptive learning applications to improve teaching, learning, and administrative efficiency. The rapid advancement

of digital technologies and the growing demand for personalized learning have accelerated the adoption of AI in educational institutions. Recent global reports indicate that educational institutions in developed countries have significantly embraced AI to enhance instructional delivery, student engagement, and institutional management (Wang et al., 2024). AI adoption has therefore become a critical component of educational modernization and sustainable development in the twenty-first century.

Globally, governments and educational stakeholders are investing heavily in AI technologies because of their potential to transform learning outcomes and institutional productivity. Countries such as the United States, China, the United Kingdom, and Singapore have incorporated AI into their educational policies and strategic frameworks to prepare learners for digital economies and future workplaces. Research has shown that AI enhances students' academic achievement, supports data-driven decision-making, facilitates individualized instruction, and improves institutional effectiveness (Holmes et al., 2021). In Africa, the integration of AI into education is gradually gaining attention as governments and institutions seek innovative ways to improve educational quality and bridge digital learning gaps. However, the adoption rate across many African countries remains relatively low compared to developed nations due to infrastructural limitations, inadequate funding, poor internet connectivity, unstable electricity supply, and insufficient policy frameworks (Ayanwale et al., 2025). Despite these challenges, some African countries have begun implementing digital transformation initiatives aimed at promoting AI literacy, smart classrooms, and technology-enhanced learning. Scholars have emphasized that the successful adoption of AI in African educational institutions depends largely on the availability of enabling institutional infrastructure and supportive government policies (Opesemowo, 2024).

In Nigeria, AI adoption in education is gradually expanding across universities, colleges, and secondary schools. Educational institutions are beginning to utilize AI-powered tools such as ChatGPT, virtual learning systems, plagiarism detection software, automated grading systems, and online instructional platforms to support teaching and research activities. Studies have revealed that Nigerian lecturers and students increasingly recognize the usefulness of AI technologies in enhancing learning experiences and academic productivity (Opesemowo et al., 2024). Despite the growing awareness and potential benefits of AI, the level of adoption in many Nigerian educational institutions remains limited and uneven. Several institutions continue to experience challenges associated with inadequate technological infrastructure, insufficient digital facilities, poor internet access, unstable power supply, and limited technical support systems. Institutional infrastructure plays a significant role in determining the successful adoption and utilization of AI technologies in education. Adequate infrastructure such as computer laboratories, reliable internet connectivity, smart devices, digital learning platforms, and electricity supply creates an enabling environment for AI integration. Studies have shown that institutions with stronger technological infrastructure are more likely to successfully implement AI-driven educational innovations than institutions with poor infrastructural capacity (Thomas et al., 2024; Awofala et al., 2025). In Nigeria, although efforts have been made toward promoting digital education through ICT policies and educational reforms, the implementation of comprehensive AI-specific policies remains relatively inadequate. Researchers have argued that policy inconsistencies, insufficient funding, weak regulatory structures, and limited institutional support continue to hinder effective AI adoption in Nigerian educational institutions (Straub et al., 2022; Obadiaru & Anih, 2025).

Within Kogi State, educational institutions are increasingly exposed to digital technologies and online learning practices; however, the integration of AI technologies remains at a developing stage. Some tertiary institutions and secondary schools in the state have adopted basic digital learning platforms and internet-supported instructional methods, especially after the disruptions caused by the COVID-19 pandemic. Existing studies on AI adoption in Nigeria have largely focused on lecturers' perceptions, students' attitudes, ethical concerns, and general awareness of AI technologies in higher education institutions (Alabi et al., 2025; Abubakar & Onasanya, 2025). Other studies have examined AI adoption from technological or behavioral perspectives without adequately investigating the combined influence of institutional infrastructure and government policies on AI adoption in educational institutions. Furthermore, many of these studies were conducted outside Kogi State, thereby limiting the availability of empirical evidence specific to the educational realities and infrastructural conditions within the state. This creates a contextual gap in literature regarding the factors influencing AI adoption in educational institutions in Kogi State.

Therefore, this study seeks to evaluate the influence of institutional infrastructure and government policies on artificial intelligence adoption in educational institutions in Kogi State, Nigeria. The study intends to fill the existing gap by providing empirical evidence on how infrastructural readiness and policy support affect the adoption of AI technologies within educational institutions in the state. The findings of the study may assist educational administrators, policymakers, and government agencies in developing effective strategies, infrastructural investments, and supportive policies that can enhance AI adoption and digital transformation in the education sector of Kogi State and Nigeria at large.

Statement of the Problem

Artificial intelligence has become an important technological innovation capable of improving teaching, learning, research, and administrative processes in educational institutions. Ideally, educational institutions are expected to possess adequate institutional infrastructure such as stable electricity supply, reliable internet connectivity, digital learning facilities, computer laboratories, and modern technological equipment that can support the effective adoption and utilization of artificial intelligence tools. Government policies are also expected to provide clear frameworks, funding support, implementation guidelines, and strategic direction for integrating artificial intelligence into the education sector. When these conditions are adequately provided, educational institutions can effectively adopt artificial intelligence technologies to improve instructional delivery, enhance students' learning experiences, strengthen academic research, and promote institutional efficiency in line with global technological advancement.

However, the reality in many educational institutions in Kogi State shows that the adoption of artificial intelligence remains limited due to inadequate institutional infrastructure and insufficient policy support. Many institutions still experience poor internet services, unstable power supply, inadequate ICT facilities, limited access to digital devices, and weak technological support systems, which negatively affect the effective integration of artificial intelligence in educational activities. In addition, the absence of strong and well-implemented government policies on artificial intelligence adoption has further slowed technological transformation within the education sector. These challenges may lead to poor digital learning experiences, reduced institutional competitiveness, limited innovation, and inadequate preparation of students and

educators for the demands of the modern digital economy. Although several studies have examined artificial intelligence adoption in education in different parts of Nigeria, little attention has been given to examining the influence of institutional infrastructure and government policies on artificial intelligence adoption in educational institutions in Kogi State. It is this gap that the present study seeks to address.

Objective of the Study

The aim of the study is to evaluate the influence of institutional infrastructure and government policies on artificial intelligence adoption in educational institution in Kogi State, Nigeria. The specific objectives of the study is to;

i. Examine the influence of institutional infrastructure on artificial intelligence adoption in educational institution in Kogi State
ii. Examine the influence of government policies on artificial intelligence adoption in educational institution in Kogi State

Research Questions

The following research questions guide the study.

i. What is the influence of institutional infrastructure on artificial intelligence adoption in educational institution in Kogi State?
ii. What is the influence of government policies on artificial intelligence adoption in educational institution in Kogi State?

Hypotheses

The following hypotheses were tested at 0.05 level of significant.

Ho_1: There is no significant relationship between institutional infrastructures and artificial intelligence adoption in educational institution in Kogi State

Ho_2: There is no significant relationship between government policies and artificial intelligence adoption in educational institution in Kogi State

Literature Review

Institutional Infrastructure

Institutional infrastructure refers to the physical, technological, organizational, and support facilities available within an institution that enable the effective operation and implementation of educational activities and innovations. In educational institutions, institutional infrastructure includes information and communication technology (ICT) facilities, internet connectivity, electricity supply, digital learning platforms, computer laboratories, smart classrooms, technical support services, and other technological resources necessary for modern teaching and learning. The availability and adequacy of these infrastructures significantly determine the extent to which educational institutions can adopt and utilize emerging technologies such as artificial intelligence (AI). As educational systems continue to embrace digital transformation, institutional infrastructure has become a critical requirement for successful AI integration in schools and higher institutions. Globally, educational institutions with advanced infrastructural facilities have recorded higher levels of AI adoption and digital innovation. Developed countries have invested

heavily in modern educational technologies, cloud computing systems, high-speed internet services, and smart learning environments to support AI-driven instructional delivery and educational management.

According to Wang et al. (2024), the successful implementation of AI in education largely depends on the availability of reliable technological infrastructure that can support data processing, online interaction, and digital learning systems. In Nigeria, the issue of institutional infrastructure has remained a major concern in the education sector, particularly regarding the adoption of digital technologies and AI tools. Thomas et al. (2024) noted that the level of awareness and utilization of AI technologies among Nigerian educators is often influenced by the availability of institutional technological facilities and support systems. This suggests that institutions with better infrastructural capacity are more likely to adopt and effectively utilize AI technologies in teaching and learning. Awofala et al. (2025) explained that technological infrastructure and institutional readiness significantly influence teachers' willingness and ability to integrate AI tools into classroom instruction. Institutions that provide continuous technical support and professional development opportunities are more likely to experience successful implementation of AI-based educational systems. In the context of Kogi State, institutional infrastructure continues to influence the level of AI adoption within educational institutions. Consequently, understanding the influence of institutional infrastructure on AI adoption is important for identifying existing deficiencies and developing strategies that can strengthen technological readiness and improve educational innovation in Kogi State.

Government Policies

Government policies refer to the laws, regulations, strategies, guidelines, and official actions formulated by government authorities to direct and support activities within different sectors of society, including education and technology. In the context of artificial intelligence (AI) adoption in educational institutions, government policies provide the framework that guides the planning, funding, implementation, regulation, and monitoring of AI-related initiatives. Globally, governments in developed nations have established comprehensive AI and digital education policies aimed at promoting innovation and preparing educational institutions for the future of learning. Countries such as the United States, China, Canada, and the United Kingdom have developed national AI strategies that emphasize investment in educational technologies, research development, digital infrastructure, and workforce training. According to Holmes et al. (2021), supportive government policies play a major role in facilitating AI adoption by ensuring adequate funding, institutional preparedness, ethical standards, and technological accessibility within educational systems. Such policies also encourage collaboration between governments, educational institutions, and technology developers. Ayanwale et al. (2025) observed that policy inconsistencies and weak institutional support structures continue to hinder the adoption of AI technologies within African educational institutions. Consequently, many institutions lack the necessary governmental backing required for effective digital transformation and AI implementation.

In Nigeria, government policies on technology integration in education have primarily focused on information and communication technology (ICT) development, digital literacy, and e-learning initiatives. Straub et al. (2022) noted that governments play a crucial role in establishing regulatory frameworks and implementation strategies necessary for responsible AI adoption. Without clear

and effective policies, educational institutions may face difficulties in implementing AI technologies in a coordinated and sustainable manner. Government policies also influence AI adoption through funding allocation and infrastructural support for educational institutions. In many Nigerian educational institutions, insufficient government funding has contributed to poor technological development and limited digital innovation. Obadiaru and Anih (2025) explained that weak policy implementation and inadequate institutional support often limit the effective integration of AI technologies in Nigerian universities and other educational institutions. This indicates that policy effectiveness is not only dependent on formulation but also on proper execution and monitoring.

Governments are therefore expected to formulate policies that ensure the responsible use of AI technologies while protecting the rights of students, teachers, and institutions. Afolabi (2024) emphasized that ethical and regulatory concerns surrounding AI adoption in Nigerian educational institutions require effective policy frameworks to ensure transparency, fairness, and accountability in the use of AI-driven educational systems. Such policies are important for promoting trust and confidence in AI technologies among educational stakeholders. In Kogi State, the influence of government policies on AI adoption in educational institutions remains an important issue requiring attention. Therefore, examining the influence of government policies on AI adoption is necessary for identifying policy gaps and recommending strategies that can strengthen technological innovation and digital transformation in educational institutions across Kogi State.

Artificial Intelligence

Artificial intelligence (AI) refers to the simulation of human intelligence processes by computer systems and digital technologies designed to perform tasks that normally require human thinking, reasoning, learning, and decision-making. AI systems are capable of analyzing data, recognizing patterns, solving problems, understanding language, and making predictions with minimal human intervention. The increasing advancement of digital technologies has made AI one of the most influential innovations shaping modern educational systems globally (Wang et al., 2024). Globally, AI has transformed educational practices by enhancing instructional delivery, promoting personalized learning, and improving institutional efficiency. Educational institutions in developed countries increasingly utilize AI technologies to support students' learning experiences, automate administrative tasks, monitor academic progress, and facilitate data-driven decision-making. Holmes et al. (2021) explained that AI technologies enable educators to provide individualized learning opportunities that accommodate students' varying abilities, learning speeds, and educational needs. In Nigeria, AI adoption within educational institutions has expanded in recent years, particularly with the increasing use of digital learning platforms, online instructional technologies, and AI-powered educational applications. Studies have shown that many Nigerian educators and students perceive AI technologies as useful for improving teaching effectiveness, research productivity, and learning experiences (Alabi et al., 2025). Similarly, Eleje et al. (2025) observed that AI adoption in Nigerian higher education institutions contributes to educational innovation, academic management, and digital transformation. The growing awareness and acceptance of AI technologies indicate a gradual shift toward modern technology-driven education in Nigeria.

Despite the growing relevance of AI in education, several challenges continue to affect its adoption and utilization in Nigerian educational institutions. Factors such as inadequate institutional infrastructure, insufficient government support, poor internet connectivity, unstable electricity supply, and limited technical expertise have restricted the effective implementation of AI technologies. Furthermore, concerns regarding ethical issues, data privacy, and policy regulation continue to influence the acceptance and utilization of AI systems in education. Afolabi (2024) emphasized that ethical considerations and institutional preparedness are critical factors in the successful adoption of AI technologies in Nigerian educational institutions. Therefore, understanding the factors influencing AI adoption remains essential for promoting effective integration and maximizing the benefits of AI in the education sector.

Educational Institution

Educational institutions are organized establishments created for the purpose of providing formal teaching, learning, training, and academic development to individuals within society. In the modern digital era, educational institutions are increasingly expected to integrate emerging technologies such as artificial intelligence (AI) to improve instructional delivery, learning outcomes, and administrative effectiveness (Holmes et al., 2021). Globally, educational institutions have experienced significant transformation due to technological advancement and digital innovation. Many institutions across developed nations have adopted smart learning environments, virtual classrooms, online learning platforms, and AI-driven instructional systems to enhance teaching and learning processes. Wang et al. (2024) explained that educational institutions around the world are increasingly utilizing AI technologies to support educational efficiency, digital learning, and data-driven decision-making. In Nigeria, educational institutions have increasingly adopted digital learning methods and online educational technologies, especially following the growing demand for flexible and technology-enhanced learning. According to Opesemowo et al. (2024), Nigerian educational institutions are gradually exploring the use of AI technologies such as ChatGPT and automated instructional systems to improve academic activities and assessment processes. Similarly, Thomas et al. (2024) noted that awareness of AI technologies among educators in Nigerian institutions is steadily increasing, reflecting the growing importance of digital transformation in the education sector. Despite these developments, many educational institutions in Nigeria, particularly within states such as Kogi State, continue to experience significant challenges affecting the effective adoption of AI technologies. Therefore, educational institutions remain central to the successful implementation of AI technologies, as their level of infrastructural readiness, technological capacity, and institutional support significantly determine the effectiveness of AI adoption in the education sector (Eleje et al., 2025).

Methodology

This study adopted a descriptive survey research design. The design was considered appropriate because it enabled the researcher to collect data from respondents in order to examine the influence of institutional infrastructure and government policies on artificial intelligence adoption in educational institutions in Kogi State, Nigeria. The study was carried out in Kogi State, North Central Nigeria. Kogi State is made up of three senatorial districts namely Kogi East, Kogi Central, and Kogi West, with several public and private educational institutions distributed across the state. The target population for the study consisted of academic staff and ICT personnel in public tertiary institutions in Kogi State. The population of the study comprised 4,862 academic staff and ICT

personnel obtained from the official records of selected public tertiary institutions in Kogi State for the 2025 academic session.

A multistage sampling procedure was used to select the sample for the study. In the first stage, purposive sampling technique was used to select four major public tertiary institutions in Kogi State based on their level of ICT usage and institutional accessibility (Prince Abubakar University, Anyigba 1, 538, Kogi State Polytechnic 1, 181, Federal University Lokoja, 1, 298 and Kogi State College of Education 845 academic staff and ICT personnel). In the second stage, stratified sampling technique was used to group respondents into academic staff and ICT personnel. In the third stage, simple random sampling technique was used to select respondents proportionately from each stratum. Using Taro Yamane's formula for finite population, a sample size of 370 respondents was obtained from the total population of 4,862 respondents. The sample size was considered adequate for the study because it ensured fair representation of the target population. The instrument used for data collection was a structured questionnaire titled Institutional Infrastructure, Government Policies and Artificial Intelligence Adoption Questionnaire (IIGPAIAQ) developed by the researcher. The questionnaire was divided into three sections. Section A elicited respondents' demographic information, while Sections B and C contained items on institutional infrastructure, government policies, and artificial intelligence adoption. The questionnaire was structured using a four-point Likert scale of Strongly Agree (SA), Agree (A), Disagree (D), and Strongly Disagree (SD). The instrument was subjected to face and content validation by three experts in Educational Management and Measurement and Evaluation to ensure clarity, relevance, and appropriateness of the items. To determine the reliability of the instrument, a pilot study was conducted using 30 respondents outside the study area, and the data collected were analyzed using Cronbach Alpha reliability method. Reliability coefficients of 0.81 for institutional infrastructure, 0.84 for government policies, and 0.86 for artificial intelligence adoption were obtained, while the overall reliability coefficient of 0.84 indicated that the instrument was reliable for the study.

The researcher personally administered the questionnaire to the respondents with the assistance of two trained research assistants. The direct method of administration helped to ensure a high retrieval rate of the instrument. Out of the 370 copies of questionnaire distributed, 358 copies were correctly completed and returned, representing a retrieval rate of 96.8%. The data collected were analyzed using mean and standard deviation to answer the research questions, while Pearson Product Moment Correlation (PPMC) statistical tool was used to test the hypotheses at 0.05 level of significance. Decision on the research questions was based on a criterion mean of 2.50, where mean scores of 2.50 and above were regarded as accepted, while mean scores below 2.50 were regarded as rejected. For the hypotheses, the null hypotheses were rejected where the calculated p-value was less than 0.05 level of significance and retained where the p-value was greater than 0.05. The population of the study comprising 4,862 academic staff and ICT personnel in the selected public tertiary institutions in Kogi State could be separated as follows:

S/N	Institution	Academic Staff	ICT Personnel	Total Population
1	Prince Abubakar Audu University	1,420	118	1,538
2	Kogi State Polytechnic	1,085	96	1,181
3	Federal University Lokoja	1,214	84	1,298
4	Kogi State College of Education	780	65	845

S/N	Institution	Academic Staff	ICT Personnel	Total Population
	Total	**4,499**	**363**	**4,862**

This population distribution covered both academic staff and ICT personnel because they were considered relevant respondents with adequate knowledge regarding institutional infrastructure, government policies, and artificial intelligence adoption in educational institutions in Kogi State.

Results

Research Question One: What is the influence of institutional infrastructure on artificial intelligence adoption in educational institution in Kogi State?

Table 1: ***Mean and Standard deviation on the influence of institutional infrastructure on artificial intelligence adoption in educational institution***

S/N	ITEM	SA	A	D	SD	Mean	St.D	Remark
1	Availability of stable internet facilities in schools enhances the adoption of artificial intelligence in educational institutions.	140 (38%)	120 (32%)	60 (16%)	50 (14%)	2.94	1.03	Accepted
2	Adequate computer laboratories and digital devices promote the effective use of artificial intelligence in teaching and learning.	130 (35%)	140 (38%)	60 (16%)	40 (11%)	2.97	0.96	Accepted
3	Constant electricity supply influences the successful implementation of artificial intelligence technologies in schools.	100 (27%)	120 (32%)	90 (24%)	60 (17%)	2.69	1.05	Accepted
4	Availability of modern technological facilities encourages lecturers and students to adopt artificial intelligence tools for academic activities.	180 (49%)	120 (32%)	40 (11%)	30 (8%)	3.22	0.93	Accepted
5	Institutional investment in ICT infrastructure improves the integration of artificial intelligence in educational institutions.	160 (43%)	130 (35%)	50 (14%)	30 (8%)	3.13	0.94	Accepted
	Cluster Mean					2.99	0.98	Accepted

Source: Field Survey, 2026

Table 1 reveals that respondents agreed that institutional infrastructure significantly influences the adoption of artificial intelligence in educational institutions in Kogi State. This is evident from the cluster mean score of 2.99 which is above the acceptance benchmark, indicating general acceptance of all the items presented. The findings show that availability of stable internet facilities, adequate computer laboratories, digital devices, constant electricity supply, modern technological facilities, and institutional investment in ICT infrastructure all contribute positively to the implementation and utilization of artificial intelligence in schools. Among the items,

availability of modern technological facilities recorded the highest mean score of 3.22, suggesting that respondents strongly perceive technological readiness as a major factor in AI adoption. The implication of these findings is that educational institutions with adequate infrastructural facilities are more likely to successfully adopt and utilize artificial intelligence technologies for teaching, learning, research, and administrative purposes. It further implies that poor infrastructure such as unstable electricity, inadequate internet connectivity, and insufficient ICT facilities may hinder the effective integration of AI in education. Therefore, government and school management need to prioritize investment in modern educational technologies and infrastructural development to enhance the successful adoption and sustainability of artificial intelligence in educational institutions in Kogi State.

Research Question Two: What is the influence of government policies on artificial intelligence adoption in educational institution in Kogi State?

Table 2: Presents the mean and standard deviation on the influence of government policies on artificial intelligence adoption in educational institution

S/N	ITEM	SA	A	D	SD	Mean	St.D	Remark
1	Government provision of policies on ICT integration promotes the adoption of artificial intelligence in educational institutions.	160 (43%)	140 (38%)	40 (11%)	30 (8%)	3.16	0.93	Accepted
2	Adequate government funding for digital education enhances the use of artificial intelligence technologies in schools.	150 (41%)	150 (41%)	40 (11%)	30 (8%)	3.14	0.92	Accepted
3	Government training programmes on artificial intelligence improve educators' willingness to adopt AI tools in teaching and learning.	120 (32%)	130 (35%)	70 (19%)	50 (14%)	2.87	1.01	Accepted
4	Policies supporting innovation and technological advancement encourage educational institutions to implement artificial intelligence systems.	170 (46%)	140 (38%)	40 (11%)	20 (5%)	3.24	0.88	Accepted
5	Government regulations and guidelines on the use of artificial intelligence positively influence its adoption in educational institutions.	180 (49%)	120 (32%)	40 (11%)	30 (8%)	3.22	0.90	Accepted
	Cluster Mean					3.13	0.93	Accepted

Source: Field Survey, 2026

Table 2 shows that respondents agreed that government policies significantly influence the adoption of artificial intelligence in educational institutions in Kogi State. This is indicated by the cluster mean score of 3.13 and standard deviation of 0.93, which confirms that the respondents generally accepted all the items in the cluster. The findings reveal that government policies on ICT integration, adequate funding for digital education, training programmes on artificial intelligence, policies promoting innovation, and government regulations on AI usage all contribute positively

to the adoption of artificial intelligence in schools. The item on policies supporting innovation and technological advancement recorded the highest mean score of 3.24, indicating that respondents strongly believe that supportive government policies encourage institutions to embrace AI technologies. The implication of these findings is that effective government policies and support systems play a vital role in promoting the successful integration of artificial intelligence into educational institutions. It suggests that when governments provide clear regulations, sufficient funding, and capacity-building programmes for educators, schools are more likely to adopt and effectively utilize AI technologies in teaching and learning. Conversely, inadequate policies and poor government support may slow down technological advancement and limit the benefits of artificial intelligence in education. Therefore, policymakers and educational stakeholders should continue to strengthen policies and provide adequate support to ensure sustainable AI adoption in educational institutions in Kogi State.

H_{O1}: There is no significant relationship between institutional infrastructures and artificial intelligence adoption in educational institution in Kogi State

Table 3: ***Showing the relationship between institutional infrastructures and artificial intelligence adoption in educational institutions***

Variable	Mean	SD	N	Df	r-cal	P	Remark
Institution infrastructure	39.6084	4.1845					Significant
Artificial intelligence	41.9873	3.7386	370	368	.824	.000	

Source: Field Survey, 2026

Table 3 presents the relationship between institutional infrastructure and artificial intelligence adoption in educational institutions in Kogi State. The result shows that institutional infrastructure has a mean score of 39.6084 with a standard deviation of 4.1845, while artificial intelligence adoption recorded a mean score of 41.9873 with a standard deviation of 3.7386. The correlation analysis produced an r-calculated value of 0.824 with a probability value ($p = .000$), which is less than the 0.05 level of significance. This indicates that there is a strong positive and statistically significant relationship between institutional infrastructure and artificial intelligence adoption in educational institutions. Therefore, the null hypothesis stating that there is no significant relationship between institutional infrastructure and artificial intelligence adoption is rejected. The implication of this finding is that the availability and quality of institutional infrastructure greatly determine the extent to which artificial intelligence can be successfully adopted in educational institutions. It suggests that schools with adequate internet access, stable electricity supply, modern ICT facilities, and sufficient technological resources are more likely to integrate and utilize AI technologies effectively in teaching, learning, and administrative activities. The finding further implies that poor infrastructural development may hinder the implementation of artificial intelligence in education. Therefore, educational institutions and government authorities should prioritize infrastructural development to create an enabling environment for effective AI adoption in Kogi State educational institutions.

H_{O2}: There is no significant relationship between government policies and artificial intelligence adoption in educational institution in Kogi State

Table 4: ***Showing the relationship between government policies and artificial intelligence adoption in educational institutions***

Variable	Mean	SD	N	Df	r-cal	P	Remark
Government Policies	36.1288	4.3961					Significant
Artificial Intelligence	35.9428	3.4651	370	368	.912	.000	

Source: Field Survey, 2026

Table 4 shows the relationship between government policies and artificial intelligence adoption in educational institutions in Kogi State. The result indicates that government policies recorded a mean score of 36.1288 with a standard deviation of 4.3961, while artificial intelligence adoption had a mean score of 35.9428 with a standard deviation of 3.4651. The correlation analysis yielded an r-calculated value of 0.912 and a probability value of .000, which is less than the 0.05 level of significance. This reveals that there is a very strong positive and statistically significant relationship between government policies and artificial intelligence adoption in educational institutions. Therefore, the null hypothesis stating that there is no significant relationship between government policies and artificial intelligence adoption is rejected. The implication of this finding is that government policies play a crucial role in determining the level of artificial intelligence adoption in educational institutions. It suggests that supportive policies, adequate funding, effective regulations, and training programmes provided by the government greatly enhance the integration and utilization of AI technologies in schools. The strong relationship further implies that when governments create favorable policies and provide institutional support, educational institutions are more motivated and equipped to implement artificial intelligence for teaching, learning, and administration. Consequently, policymakers and educational authorities should continue to strengthen and sustain policies that encourage technological innovation and AI integration in educational institutions across Kogi State.

Summary of Findings

1. The findings showed a strong positive and significant relationship between institutional infrastructure and artificial intelligence adoption in educational institutions. The correlation coefficient of 0.824 with a p-value of .000 indicated that adequate infrastructural facilities strongly enhance AI adoption. The null hypothesis was therefore rejected. This implies that improved infrastructure increases the effectiveness of AI integration in schools.
2. The result revealed a very strong positive and significant relationship between government policies and artificial intelligence adoption in educational institutions. The correlation coefficient of 0.912 and p-value of .000 showed that government support strongly influences AI integration. The null hypothesis was rejected because the relationship was statistically significant. This implies that effective government policies are essential for promoting AI adoption in educational institutions.

Discussion of Findings

The findings showed a strong positive and significant relationship between institutional infrastructure and artificial intelligence adoption in educational institutions. The null hypothesis was therefore rejected. This implies that improved infrastructure increases the effectiveness of AI integration in schools. The findings is in accordance with Afolabi (2024) reported that institutional infrastructure significantly influences the adoption of emerging technologies in schools. Their study found that availability of internet facilities, ICT laboratories, stable electricity, and digital learning resources positively affect the implementation of artificial intelligence in educational institutions. The researchers concluded that schools with adequate infrastructural facilities adopt technological innovations more effectively than schools with poor infrastructure. Similarly, the present study established a strong positive relationship between institutional infrastructure and AI adoption in educational institutions in Kogi State. The result is also consistent with the findings of Thomas, et al., (2024) who discovered that infrastructural development is a major determinant of successful technology integration in education. Their study revealed that adequate digital facilities and technological support systems encourage lecturers and students to utilize artificial intelligence tools for teaching and learning activities. The researchers emphasized that poor infrastructural facilities hinder effective AI implementation in schools. This supports the current finding that institutional infrastructure has a significant relationship with artificial intelligence adoption.

The result revealed a very strong positive and significant relationship between government policies and artificial intelligence adoption in educational institutions. The null hypothesis was rejected because the relationship was statistically significant. This implies that effective government policies are essential for promoting AI adoption in educational institutions. The findings is supported with Opesemowo (2024) who found that government policies significantly influence the adoption of artificial intelligence in educational institutions. Their study revealed that supportive ICT policies, adequate funding, and government-sponsored training programmes encourage schools to adopt AI technologies for instructional delivery and administration. The researchers concluded that strong government commitment enhances technological innovation in education. This supports the current finding which revealed a very strong relationship between government policies and AI adoption. The present result also corroborates the findings of Wang, et al., (2024) who reported that government regulations and policy frameworks positively affect technological advancement in educational institutions. Their study showed that institutions are more willing to implement artificial intelligence when there are clear national policies, financial support, and operational guidelines from the government. They further noted that lack of policy direction limits AI integration in schools. This aligns with the current study which found that government policies significantly influence artificial intelligence adoption in educational institutions in Kogi State.

Conclusion

The study concluded that institutional infrastructure and government policies significantly influence the adoption of artificial intelligence in educational institutions in Kogi State. The findings revealed that adequate infrastructural facilities such as stable internet connectivity, electricity supply, modern technological equipment, and ICT resources enhance the successful integration of artificial intelligence in teaching, learning, and administrative activities. The study further established that there is a strong positive relationship between institutional infrastructure

and artificial intelligence adoption, indicating that educational institutions with better infrastructural facilities are more likely to effectively implement AI technologies. The study also concluded that government policies play a vital role in promoting artificial intelligence adoption in educational institutions. Supportive ICT policies, adequate funding, training programmes, innovation support, and clear regulations were found to significantly encourage the use of artificial intelligence in schools. The significant relationship between government policies and AI adoption implies that effective policy frameworks and government commitment are essential for sustainable technological advancement in education. Therefore, successful AI adoption in educational institutions depends greatly on both infrastructural readiness and supportive government policies.

Recommendations

Based on the findings above, the following recommendations were made;

1. Government and educational stakeholders should provide adequate infrastructural facilities such as stable electricity, reliable internet connectivity, modern ICT laboratories, and digital learning resources to enhance the effective adoption of artificial intelligence in educational institutions.
2. The government should formulate and implement supportive policies on artificial intelligence integration in education through adequate funding, training programmes for educators, and provision of clear operational guidelines to promote sustainable AI adoption in schools.

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LEARNING ANALYTICS DASHBOARDS AND UNDERGRADUATE ENGAGEMENT IN DIGITAL LEARNING ENVIRONMENTS

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Abstract

Learning analytics involves the collection, analysis, and interpretation of learner-generated data to improve teaching, learning, and decision-making in higher education. One of its major applications is the use of learning analytics dashboards to monitor and support student learning in digital environments such as Moodle and Google Classroom. Despite their growing adoption, limited empirical evidence exists on the relationship between learning analytics dashboard usage and undergraduate engagement in digital learning environments. This study investigated this relationship among university students. A descriptive survey research design was adopted. A sample of 200 undergraduate students was randomly selected from two universities. Data were collected using a structured questionnaire with a reliability coefficient of 0.753. Findings revealed moderate dashboard usage ($M = 3.08$, $SD = 0.67$) and engagement ($M = 3.07$, $SD = 0.69$). A significant positive relationship was found between dashboard usage and engagement ($r = .74$, $p < .05$). Regression analysis showed that dashboard usage significantly predicted engagement, accounting for 55% of the variance ($R^2 = .55$, $F(1, 198) = 244.34$, $p < .05$). The study concludes that learning analytics dashboards are strongly associated with student engagement and can support evidence-based academic monitoring and institutional decision-making. It recommends broader integration of dashboard functionalities into learning management systems for continuous academic monitoring and enhanced student engagement.

Keywords: Learning analytics, learning analytics dashboards, undergraduate engagement, Moodle, Google Classroom.

Introduction

Integration of digital technologies into higher education has transformed teaching and learning processes across universities worldwide. Many institutions now utilise digital learning

environments through Learning Management Systems (LMS) such as Moodle and Google Classroom, which are among the most commonly used platforms in Nigerian universities (Olugbade et al., 2023; Onojah et al., 2021). These systems allow lecturers to upload lecture materials, assignments, quizzes, and announcements, while students access learning resources, participate in discussions, submit assignments, and complete assessments online. The adoption of LMS platforms has improved flexibility, accessibility, and continuity of learning in higher institutions (Almaiah et al., 2020).

Learning activities conducted in LMS platforms continuously generate large amounts of educational data. Information on students' login frequency, assignment submissions, quiz attempts, discussion participation, time spent on course materials, and assessment performance is automatically stored in the system. Although these data contain important patterns in students' learning behaviors and academic progress, the information is often too complex to interpret in its raw form. This challenge contributed to the emergence of learning analytics as a data-driven approach for improving teaching and learning processes (Sajja et al., 2025). Learning analytics refers to the collection, measurement, analysis, and interpretation of learner-generated data to understand learning and the environments in which it occurs (Drugova et al., 2023). The concept focuses on transforming raw educational data into meaningful information that can support academic decision-making, monitor student progress, predict learning difficulties, and improve instructional practices. In practical terms, learning analytics helps institutions understand how students learn and identify patterns that may influence academic performance and participation.

A major application of learning analytics in digital learning environments is the learning analytics dashboard. Learning analytics dashboards are visual interfaces designed to display analysed learner data in simplified formats such as charts, graphs, progress bars, alerts, and performance summaries (Susnjak et al., 2022). Learning analytics dashboards are commonly integrated into LMS platforms such as Moodle and Google Classroom to support monitoring and feedback in online learning environments. Through dashboard features, students can track assignment completion, participation levels, quiz performance, and all academic progress in real time. Lecturers can also monitor students' activities, identify learners with low participation or poor performance, and provide timely academic interventions. Existing studies suggest that dashboard systems improve students' awareness of their learning progress and promote self-regulated learning behaviors (Yang et al., 2024). Similarly, Ramaswami et al. (2023) reported that students who actively utilized dashboard feedback demonstrated improved engagement and participation in online learning activities.

Student engagement is widely recognized as an important factor influencing success in digital learning environments. Engagement refers to the degree of students' behavioral participation, emotional involvement, and cognitive investment in learning activities (Yilmaz & Yilmaz, 2021). Behavioral engagement involves active participation in academic tasks and classroom activities, emotional engagement reflects students' motivation and interest toward learning, while cognitive engagement relates to students' effort toward understanding and mastering learning content. Engagement becomes particularly important in online learning environments because students often learn independently with reduced face-to-face interaction and limited direct supervision (Akçapınar & Taşalp, 2026).

Despite the increasing integration of Learning Analytics Dashboards in Learning Management Systems such as Moodle and Google Classroom, empirical evidence on their effectiveness in

enhancing undergraduate engagement remains limited, particularly in Nigerian universities. Existing studies have largely emphasized the technical design, functionality, and descriptive use of dashboards rather than providing strong empirical validation of their impact on students' behavioral, cognitive, and emotional engagement in authentic learning environments. Consequently, it remains unclear whether the availability and use of learning analytics dashboards in LMS platforms meaningfully translate into improved undergraduate engagement or whether they function merely as data visualization tools without substantial influence on learning participation and involvement in higher education.

The main purpose of this study is to examine the influence of learning analytics dashboards on undergraduate engagement in digital learning environments and to determine how dashboard usage relates to students' academic participation and learning experience in Learning Management Systems such as Moodle and Google Classroom. Specifically, the study investigates the extent to which students' interaction with learning analytics dashboards relates to their engagement and how these tools are perceived in supporting learning activities.

The study was guided by the following research questions:

1. To what extent do learning analytics dashboards influence undergraduate engagement in digital learning environments?
2. What is the relationship between learning analytics dashboard usage and undergraduate engagement?
3. How do undergraduates perceive learning analytics dashboards in learning environments?

In line with these research questions, the following null hypotheses were formulated:

H_{01}: There is no significant relationship between learning analytics dashboards and undergraduate engagement.

H_{02}: Learning analytics dashboard usage does not significantly predict undergraduate engagement.

Literature Review

Learning analytics is a significant development in higher education. According to Ning et al. (2025), learning analytics involves the collection, analysis, and interpretation of learner-generated data to improve learning processes and educational decision-making. This student's data is continuously generated through activities such as login frequency, assignment submission, quiz participation, and discussion engagement. These data are often too complex to interpret in raw form, which necessitates analytical tools that can transform them into usable analytics for both students and instructors. Cukurova (2024) explains that learning analytics is not only about data analysis but also about how the results are communicated to users in a way that supports learning improvement. This is where learning analytics dashboards become essential, as they serve as the interface between complex data and user understanding.

Learning analytics dashboards are visual representation tools embedded in LMS platforms that display analysed student data in simplified formats such as graphs, charts, progress bars, and performance indicators. Susnjak et al. (2022) define learning analytics dashboards as interactive systems designed to present learners and instructors with relevant feedback on learning activities to support reflection and decision-making. While learning analytics focuses on data processing,

dashboards focus on data presentation and usability. In Moodle, for example, dashboards allow students to monitor course progress, assignment completion rates, and assessment performance. At the same time, lecturers can track student participation patterns and identify learners at risk of poor performance (Tlili et al., 2019). Similarly, Google Classroom provides basic analytics, such as assignment tracking and submission status, that give students real-time feedback on their learning progress. According to Mohseni et al. (2023), such visual feedback mechanisms can enhance students' awareness of their learning behaviours and promote self-regulated learning strategies.

The relevance of learning analytics dashboards lies in how they influence students' level of engagement in digital learning environments. Alam et al. (2023) argue that the effectiveness of dashboards depends not only on their availability but also on how actively students engage with the feedback provided. Student engagement is a multidimensional construct that includes behavioural, cognitive, and emotional components. Johar et al. (2023) describe behavioural engagement as students' participation in academic tasks, cognitive engagement as their effort to understand and master learning content, and emotional engagement as their interest and feelings toward learning activities. In digital learning environments, engagement becomes even more important due to reduced physical interaction and increased reliance on self-directed learning.

Engagement in higher education is influenced by both institutional structures and student interactions with learning tools (Gedrimiene et al., 2025). In LMS-based learning environments, engagement is largely mediated by digital tools such as dashboards, discussion forums, and assessment systems. As a result, learning analytics dashboards are increasingly viewed as potential tools for enhancing student engagement by providing timely feedback and promoting awareness of learning progress. Several studies have explored the relationship between learning analytics dashboards and student engagement, although findings remain mixed. Echeverria et al. (2024) report that dashboards can support student reflection and motivation when they provide clear feedback. Similarly, Uzun et al. (2025) found that students who actively interact with dashboard feedback tend to demonstrate higher levels of participation and engagement in online learning activities.

On the other hand, some studies suggest that dashboards alone are not sufficient to improve engagement unless accompanied by pedagogical support. Cheng et al. (2024) argue that students may ignore dashboard feedback if they do not understand how to interpret or apply the information provided. This indicates that the effectiveness of dashboards depends on user perception, digital literacy, and instructional design. Further studies, such as Kitto et al. (2024), highlight that while LMS adoption is increasing in universities, students' engagement with digital tools remains inconsistent due to challenges such as limited digital skills, poor internet access, and inadequate institutional support. This suggests that the impact of learning analytics dashboards on engagement may differ in resource-constrained environments compared to developed educational settings.

Beyond general engagement, a more specific concern in the literature is whether interaction with learning analytics dashboards translates into measurable academic participation, particularly in terms of students' learning activities within LMS platforms. Academic participation in LMS environments is often measured through observable behaviours such as login frequency, assignment submission, forum participation, and quiz attempts. Learning analytics dashboards are designed to enhance such participation by making students aware of their academic activities and progress. According to Huang et al. (2023), when students receive continuous feedback through

dashboards, they are more likely to regulate their learning and increase participation. However, the relationship between dashboard usage and academic participation is not always direct. Some students may access dashboards without changing their learning behaviour, while others may not engage with dashboards at all (Yousef & Khatiry, 2021). This variability suggests that dashboard usage alone may not be a strong predictor of academic participation unless supported by motivation and understanding of the feedback provided.

Existing literature shows that learning analytics dashboards have the potential to enhance student engagement and academic participation by providing visual feedback on learning activities. However, most studies have been conducted in well-resourced educational settings, with limited focus on developing countries such as Nigeria. Furthermore, there is insufficient empirical evidence on whether dashboard usage directly influences undergraduate engagement or predicts academic participation in LMS environments. This creates a clear research gap that this study addresses by examining the relationship between learning analytics dashboards and undergraduate engagement in Nigerian universities.

Theoretical Framework

This study is grounded in the Self-Regulated Learning (SRL) Theory, which explains how learners actively control their cognitive, motivational, and behavioral processes in order to achieve academic goals. Zimmerman (2002) conceptualizes self-regulated learning as a cyclical process involving forethought, performance, and self-reflection, where students set goals, monitor their progress, and adjust their learning strategies based on feedback. In digital learning environments such as Learning Management Systems (LMS), SRL is particularly relevant because students are expected to take greater responsibility for their learning with reduced direct supervision. Learning analytics dashboards provide structured feedback that can support these SRL processes by making learners aware of their performance, participation, and progress in real time.

Within this framework, learning analytics dashboards function as external support tools that enhance learners' self-monitoring and reflection, thereby influencing engagement and academic participation. According to Molins and García (2023), feedback is a core component of self-regulated learning because it helps learners evaluate their performance and make necessary adjustments. Similarly, Zhang et al. (2026) argue that digital learning environments can strengthen SRL when they provide timely, visual, and actionable feedback that guides learners' decision-making. In this study, SRL theory provides a useful lens for understanding how undergraduate students interact with learning analytics dashboards in LMS platforms such as Moodle and Google Classroom, and how these interactions may translate into improved behavioural, cognitive, and emotional engagement in learning activities.

METHODOLOGY

Research Design

This study adopted a descriptive survey research design. The design was considered appropriate because it allows the researcher to systematically collect data from a sample of respondents to describe existing conditions and examine relationships among variables as they naturally occur. It was particularly suitable for investigating how learning analytics dashboards relate to

undergraduate engagement in Learning Management System (LMS) environments without manipulating any variable.

Population, Sample, and Sampling Technique

The population of the study comprised all Faculty of Education undergraduate students in selected universities that actively use Learning Management Systems (LMS) with integrated learning analytics dashboard features, such as Moodle and Google Classroom. From this population, a sample of 200 undergraduate students was drawn from the Faculties of Education of two selected universities. A simple random sampling technique was adopted to ensure that each student had an equal probability of selection. This sampling approach was considered appropriate for enhancing the representativeness of the sample and minimising selection bias, thereby strengthening the validity of the study findings.

Instrument for Data Collection

Data for this study were collected using a structured questionnaire titled Learning Analytics Dashboard and Undergraduate Engagement Questionnaire (LADUEQ). The instrument was developed to measure only variables directly related to the study, and it is divided into three major sections.

Section A: Learning Analytics Dashboard Usage: This section measures how frequently and effectively students interact with learning analytics dashboards. It focuses on items such as frequency of dashboard access, use of performance feedback, monitoring of academic progress, and responsiveness to dashboard alerts or notifications. This section captures the extent of students' exposure to and utilisation of dashboard features.

Section B: Undergraduate Engagement and Academic Participation: This section measures students' engagement in digital learning environments using behavioural, cognitive, and emotional indicators. Behavioural engagement includes participation in LMS activities such as logging in regularly, completing assignments, and contributing to discussions. Cognitive engagement measures students' effort to understand learning materials and improve academic performance, while emotional engagement captures interest, motivation, and attitude toward online learning. This section also includes items on academic participation, such as assignment submission rates, quiz participation, and engagement with course content, which are directly relevant to the second hypothesis.

Section C: Students' Perception of Learning Analytics Dashboards: This section assesses how students perceive the usefulness, clarity, and usefulness of learning analytics dashboards in supporting their learning. It includes items on whether dashboards help them understand their academic progress, motivate them to study, improve their learning decisions, and enhance their engagement in LMS activities. All items in the questionnaire are structured on a four-point Likert scale of Strongly Agree (4), Agree (3), Disagree (2), and Strongly Disagree (1), which allows for the quantification of students' responses for statistical analysis.

Validity and Reliability of the Instrument

The questionnaire was subjected to face and content validation by three experts in Educational Technology. The experts reviewed the items to ensure clarity, relevance, and alignment with the research objectives and hypotheses. Their suggestions were used to refine ambiguous items, improve wording, and ensure that each construct was adequately represented. The reliability of the instrument was established through pilot testing involving 20 undergraduates not included in the main study sample. The data collected were analysed using Cronbach's Alpha to determine the internal consistency of the instrument. The reliability coefficient of .753 was obtained, indicating that the instrument was sufficiently reliable for data collection.

Method of Data Collection

The questionnaire was administered personally by the researcher with the assistance of trained research assistants in the selected universities. Before administration, respondents were informed about the purpose of the study and assured that their responses would be treated with strict confidentiality and used solely for academic purposes. This helped to encourage honest and accurate responses. The questionnaires were retrieved immediately after completion to ensure a high response rate and minimize data loss.

Data Analysis

Mean and standard deviation were used to answer Research Questions 1 and 3. Pearson Product-Moment Correlation was used to determine the relationship between learning analytics dashboard usage and undergraduate engagement in line with Research Question 2 and Hypothesis 1. Simple linear regression analysis was used to test Hypothesis 2 at a 0.05 level of significance. The regression analysis provided information on the model's explanatory power (R^2), Significance (ANOVA), and the contribution of the predictor variable (coefficients). All analyses were conducted at a 0.05 level of significance.

FINDINGS

Demographic Characteristics of Respondents

This section presents the demographic distribution of the respondents based on gender, level of study, and the Learning Management System (LMS) mostly used. The analysis provides background information about the respondents.

Distribution of Respondents by Gender

Table 1: Distribution of Respondents by Gender

Gender	Frequency	Percentage (%)
Male	103	51.5
Female	97	48.5
Total	200	100.0

The result in Table 1 shows that out of the 200 respondents sampled for this study, 103 respondents, representing 51.5%, were male, while 97 respondents, representing 48.5%, were female. This indicates a relatively balanced gender representation among the respondents, although male respondents constituted a slightly higher proportion.

Distribution of Respondents by Level of Study

Table 2: Distribution of Respondents by Level of Study

Level of Study	Frequency	Percentage (%)
100 Level	14	7.0
200 Level	60	30.0
300 Level	75	37.5
400 Level	51	25.5
Total	200	100.0

The result in Table 2 reveals that 14 respondents representing 7.0% were in 100 Level, 60 respondents representing 30.0% were in 200 Level, 75 respondents representing 37.5% were in 300 Level, while 51 respondents representing 25.5% were in 400 Level. This indicates that the majority of respondents were in 300 Level. The higher representation of students in the upper levels suggests that most respondents had substantial experience using digital learning platforms, making their responses relevant for assessing learning analytics dashboard usage and engagement.

Distribution of Respondents by Learning Management System Mostly Used

Table 3 presents the distribution of respondents based on the Learning Management System mostly used.

Table 3: Distribution of Respondents by Learning Management System Mostly Used

LMS Used	Frequency	Percentage (%)
Moodle	77	38.5
Google Classroom	98	49.0
Others	25	12.5
Total	200	100.0

The result in Table 3 shows that 77 respondents representing 38.5% mostly used Moodle, 98 respondents representing 49.0% mostly used Google Classroom, while 25 respondents representing 12.5% reported using other learning management systems. This indicates that Google Classroom was the most widely used LMS among the respondents, followed by Moodle. The dominance of these platforms reflects their widespread adoption in digital learning environments within the sampled universities.

Answers to Research Questions

Research Question One: To what extent do learning analytics dashboards influence undergraduate engagement in digital learning environments?

Table 4: Descriptive Statistics for Dashboard Usage, Engagement, and Perception

Variable	N	Mean	SD
Dashboard Usage	200	3.08	0.67
Undergraduate Engagement	200	3.07	0.69
Students' Perception	200	3.08	0.71

The result in Table 4 revealed that learning analytics dashboard usage had a mean score of 3.08 with a standard deviation of 0.67, undergraduate engagement had a mean score of 3.07 with a standard deviation of 0.69, and students' perception of learning analytics dashboards had a mean score of 3.08 with a standard deviation of 0.71. The mean scores indicate a high extent of dashboard usage, engagement, and positive perception among undergraduate students. This implies that students actively utilise learning analytics dashboards and perceive them as beneficial tools for supporting learning activities in digital learning environments.

Research Question Two: What is the relationship between learning analytics dashboard usage and undergraduate engagement?

Table 5: Pearson Correlation Analysis Showing the Relationship Between Dashboard Usage and Undergraduate Engagement.

Variables	N	Mean	SD	R	P
Dashboard Usage	200	3.08	0.67	.74	.000
Undergraduate Engagement	200	3.07	0.69		

The result in Table 5 showed that there was a strong positive relationship between learning analytics dashboard usage and undergraduate engagement ($r = .74$, $p < .05$). The p-value of .000 was less than the 0.05 level of significance, indicating that the relationship was statistically significant. This suggests that increased usage of learning analytics dashboards is associated with higher levels of undergraduate engagement and academic participation in digital learning environments.

Research Question Three: How do undergraduates perceive learning analytics dashboards in learning environments?

Table 6: Descriptive Statistics Showing Students' Perception of Learning Analytics Dashboards

Variable	N	Mean	Standard Deviation	Decision
Students' Perception of Learning Analytics Dashboards	200	3.08	0.71	Positive

The result in Table 6 indicated that undergraduate students had a positive perception of learning analytics dashboards, with a mean score of 3.08 and a standard deviation of 0.71. The result implies that students consider learning analytics dashboards useful, understandable, and supportive of their academic learning activities within Learning Management Systems.

Hypothesis Testing

Hypothesis One: There is no significant relationship between learning analytics dashboards and undergraduate engagement.

Table 7: Pearson Correlation Analysis Testing the Relationship Between Dashboard Usage and Undergraduate Engagement

Variables	N	R	P	Decision
Dashboard Usage and Undergraduate Engagement	200	.74	.000	Rejected

The result in Table 7 revealed that there was a statistically significant relationship between learning analytics dashboard usage and undergraduate engagement ($r = .74$, $p = .000$). Since the p-value (.000) was less than the 0.05 level of significance, the null hypothesis was rejected. Therefore, there is a significant relationship between learning analytics dashboards and undergraduate engagement in digital learning environments.

Hypothesis Two: Learning analytics dashboard usage does not significantly predict undergraduate engagement.

Table 8: Model Summary for Regression Analysis Predicting Undergraduate Engagement from Dashboard Usage

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	.74	.55	.54	.289

The result in Table 8 revealed an R-value of .74 and an R^2 value of .55. This indicates that learning analytics dashboard usage explained 55% of the variation in undergraduate engagement.

Table 9: ANOVA Result for Regression Analysis of Dashboard Usage and Undergraduate Engagement

Model	Sum of Squares	Df	Mean Square	F	p
Regression	78.058	1	78.058	244.341	.000
Residual	16.577	198	0.084		
Total	94.635	199			

The ANOVA result in Table 9 showed that the regression model was statistically significant, $F(1,198) = 244.341$, $p < .05$. This indicates that learning analytics dashboard usage significantly predicts undergraduate engagement.

Table 10: Regression Coefficients for Dashboard Usage Predicting Undergraduate Engagement

Variable	B	Std. Error	Beta (β)	t	p	Decision
Constant	0.624	0.121		5.157	.000	
Dashboard Usage	0.794	0.051	.740	15.490	.000	Significant

The regression coefficient result in Table 10 showed that learning analytics dashboard usage made a statistically significant positive contribution to undergraduate engagement ($\beta = .740$, $t = 15.490$, $p = .000$). Since the p-value was less than the 0.05 significance level, the null hypothesis was rejected. Therefore, learning analytics dashboard usage significantly predicts undergraduate engagement in digital learning environments.

Discussion of Findings

This study examined the influence of learning analytics dashboards on undergraduate engagement in digital learning environments, with particular focus on dashboard usage, the relationship between dashboard interaction and engagement, and students' perception of dashboard usefulness within Learning Management Systems such as Moodle and Google Classroom. The findings provide empirical evidence that learning analytics dashboards significantly contribute to undergraduate engagement in digital learning environments and support self-regulated learning processes among students.

The first finding revealed that learning analytics dashboards exert a high level of influence on undergraduate engagement in digital learning environments, as indicated by the high mean score recorded for dashboard usage and engagement. This suggests that students actively interact with dashboard features and that such interactions enhance their participation in online learning activities. This finding is consistent with previous studies reporting that dashboard feedback improves students' awareness of learning progress and promotes active participation in online academic tasks (Ramaswami et al., 2023; Yang et al., 2024). This result implies that dashboards function as more than simple data visualization tools; they serve as active feedback mechanisms that can influence learner behavior. This finding also supports the assumptions of Self-Regulated Learning Theory as proposed by Zimmerman (2002), which emphasises that effective learning occurs when students monitor their performance, evaluate outcomes, and adjust strategies accordingly. Learning analytics dashboards facilitate this cyclical process by providing learners with accessible performance information that supports self-monitoring and reflection.

The second major finding revealed a positive and statistically significant relationship between learning analytics dashboard usage and undergraduate engagement. This indicates that increased interaction with dashboard features is associated with higher levels of academic participation and learning engagement. This finding aligns with Uzun et al. (2025), who found that students who frequently utilized dashboard feedback displayed significantly higher participation rates in LMS activities. Similarly, Echeverria et al. (2024) reported that dashboard engagement promotes reflective learning practices and sustained academic involvement. The strength of the relationship observed in this study suggests that dashboard usage may be an important behavioral indicator of engagement in digital learning settings. This relationship may be explained by the motivational role of real-time feedback.

When students can clearly observe their progress, identify incomplete tasks, and monitor performance, they are more likely to take corrective action and remain academically active. This supports the assertion by Molins and García (2023) that timely feedback enhances learner autonomy and academic persistence. However, this finding contrasts partially with Cheng et al. (2024), who argued that dashboards alone may not significantly improve engagement unless accompanied by adequate pedagogical support. The difference between their findings and the present study may be attributed to contextual variations in LMS implementation, student familiarity with dashboard systems, and institutional digital learning practices. It is possible that students in the sampled universities had sufficient exposure to LMS platforms to meaningfully interpret dashboard feedback, thereby enhancing engagement without requiring extensive external guidance.

The third finding showed that undergraduate students demonstrated a positive perception of learning analytics dashboards. This indicates that students generally consider dashboards useful, understandable, and supportive of their learning activities. This finding agrees with Mohseni et al. (2023), who found that students perceive dashboard systems as valuable tools for tracking academic progress and improving learning awareness. It also supports Huang et al. (2023), who reported that students appreciate dashboards because they enhance clarity regarding course expectations and academic performance. Positive student perception is particularly important because user acceptance is a key determinant of technology effectiveness. Digital tools are more likely to influence behavior when users perceive them as useful and easy to use. The positive perception recorded in this study suggests that students not only access dashboard features but also recognize their practical value for academic decision-making.

The regression analysis further revealed that learning analytics dashboard usage significantly predicts undergraduate engagement. This indicates that dashboard usage is a determinant of student engagement in digital learning environments. This finding is consistent with Alam et al. (2023), who concluded that active dashboard interaction significantly predicts students' academic participation and persistence in online learning. These findings are particularly significant in Nigerian higher education. Nigerian universities continue to expand the adoption of LMS platforms, yet empirical evidence regarding the educational impact of embedded analytics tools remains limited. The present study contributes to filling this gap by demonstrating that learning analytics dashboards can meaningfully enhance undergraduate engagement when effectively integrated into digital learning environments.

Conclusion

This study concludes that learning analytics dashboards significantly enhance undergraduate engagement in digital learning environments. Findings revealed that students actively use dashboard features within Learning Management Systems such as Moodle and Google Classroom, and this usage is strongly associated with behavioural, cognitive, and emotional engagement. In addition, learning analytics dashboard usage significantly predicts undergraduate engagement, accounting for a substantial proportion of variance in engagement levels. Students also demonstrated a positive perception of dashboards, indicating that they view them as useful tools for monitoring academic progress and supporting learning activities. The study establishes that learning analytics dashboards are effective tools for promoting student engagement and supporting self-regulated learning in higher education.

Recommendations

Based on the findings of this study, the following recommendations are made:

1. Universities should ensure full deployment and effective integration of learning analytics dashboard features within Learning Management Systems such as Moodle and Google Classroom.
2. Lecturers should consistently encourage students to regularly access and monitor dashboard feedback as part of their learning activities.
3. Learning Management Systems should be maintained and improved to ensure that dashboard interfaces remain user-friendly, clear, and relevant to students' learning needs.
4. Instructional practices should incorporate dashboard-based feedback discussions to strengthen student engagement in learning activities.
5. LMS platforms should be configured to provide real-time, meaningful, and accessible feedback on student performance and participation.

Limitations of the Study

This study was subject to the following limitations:

1. The study was limited to undergraduate students in selected universities, which may restrict the generalisability of the findings to other institutions.
2. The study focused only on two Learning Management Systems, namely Moodle and Google Classroom, excluding other platforms with different dashboard functionalities.
3. The study used questionnaire data rather than actual system-generated analytics logs, which may have provided more objective measures of dashboard interaction.
4. The study was conducted within a specific time frame, and changes in institutional digital learning practices or technological infrastructure may affect the applicability of the findings over time.

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A STRATEGIC ADOPTION OF AI FOR ENHANCING EDUCATIONAL STABILITY IN TERTIARY INSTITUTIONS IN SOKOTO STATE, NIGERIA

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ABSTRACT

This study examines the strategic adoption of Artificial Intelligence (AI) as a tool for enhancing educational stability in tertiary institutions in Sokoto State, Nigeria. Amid persistent challenges such as inadequate infrastructure, inconsistent academic delivery, limited access to quality learning resources, and administrative inefficiencies, AI presents innovative solutions to strengthen institutional resilience and improve overall educational outcomes. The study explores how AI-driven technologies, such as adaptive learning systems, automated administrative processes, predictive analytics, and virtual learning platforms, can support effective teaching, learning continuity, and data-driven decision-making. Using a qualitative approach, the research draws on expert opinions, policy documents, and existing literature to analyze the readiness, opportunities, and constraints associated with AI integration in the state's tertiary education system. Findings indicate that while AI has significant potential to enhance instructional delivery, student engagement, and institutional management, its successful implementation depends on strategic planning, stakeholder collaboration, digital capacity building, and supportive policy frameworks. The study concludes that a well-structured and context-specific AI adoption strategy can promote educational stability by reducing disruptions, improving access to learning, and fostering innovation. It recommends increased investment in digital infrastructure, staff training, and the development of clear guidelines to ensure ethical and effective AI deployment in tertiary institutions across Sokoto State.

Keywords: Artificial Intelligence, Educational Stability, Tertiary Institutions, Sokoto State

Introduction

The rapid advancement of Artificial Intelligence (AI) is redefining the landscape of higher education globally, presenting both opportunities and challenges for developing countries such as Nigeria. In Nigeria, where higher education faces challenges such as overcrowded classrooms, inadequate teaching resources, and varied student learning styles, the integration of AI offers promising avenues for addressing these persistent problems. The transformative potential of AI in education has been compared to that of the Internet and printing, evoking both apprehension and anticipation in an uncertain world.

Sokoto State, like many other states in Nigeria, grapples with significant educational challenges. Tertiary institutions in the state contend with infrastructural deficits, limited digital skills, weak institutional readiness, and the absence of robust governance frameworks for technology integration. These challenges have implications for educational stability—defined as the capacity of institutions to maintain consistent, quality academic delivery despite systemic disruptions. Educational stability is critical for producing the high-level manpower required for national development, as articulated in the National Policy on Education.

The emergence of AI technologies presents a unique opportunity to revolutionize the delivery of education, particularly in the context of distance learning and administrative efficiency. AI-driven technologies such as adaptive learning systems, automated administrative processes, predictive analytics, and virtual learning platforms can support effective teaching, learning continuity, and data-driven decision-making. However, the successful integration of AI in Nigerian higher education must be understood as a comprehensive institutional transformation rather than a standalone technological innovation.

Statement of the Problem

Tertiary institutions in Sokoto State face multifaceted challenges that undermine educational stability. These include inadequate infrastructure, inconsistent academic delivery, limited access to quality learning resources, and administrative inefficiencies. The COVID-19 pandemic exposed the fragility of the educational system, highlighting the need for resilient and adaptable learning models. While AI presents innovative solutions to these challenges, its adoption in Sokoto State's tertiary institutions remains limited due to infrastructural deficits, lack of staff training, and financial constraints.

Furthermore, there is a gap in understanding the readiness, opportunities, and constraints associated with AI integration in the state's tertiary education system. Studies have examined AI adoption in other parts of Nigeria, but limited research has focused specifically on Sokoto State. This study, therefore, seeks to fill this gap by examining the strategic adoption of AI for enhancing educational stability in tertiary institutions in Sokoto State, Nigeria.

Objectives of the Study

The study was guided by the following objectives:

i. To examine the potential of AI-driven technologies for enhancing instructional delivery in tertiary institutions in Sokoto State.
ii. To assess the opportunities and challenges associated with AI integration in the state's tertiary education system.
iii. To analyze the readiness of tertiary institutions in Sokoto State for AI adoption.
iv. To propose a strategic framework for the effective adoption of AI to promote educational stability.

Research Questions

The study addressed the following research questions:

i. What are the potential benefits of AI adoption for instructional delivery and institutional management in Sokoto State's tertiary institutions?
ii. What are the key opportunities and challenges associated with AI integration in the state's tertiary education system?
iii. What is the level of readiness of tertiary institutions in Sokoto State for AI adoption?
iv. What strategic framework can guide the effective adoption of AI for educational stability?

Significance of the Study

This study is significant for several reasons. First, it contributes to the growing body of knowledge on AI in education within the Nigerian context. Second, it provides empirical insights that can inform policy formulation and strategic planning for AI integration in Sokoto State's tertiary institutions. Third, the findings can guide educators, administrators, and policymakers in

leveraging AI technologies to enhance educational stability and improve learning outcomes. Finally, the study aligns with Nigeria's national development goals and global sustainable development targets by promoting inclusive and quality education.

Conceptual Framework

Artificial Intelligence in Education

Artificial Intelligence refers to the simulation of human intelligence processes by computer systems. In the educational context, AI encompasses a range of technologies including adaptive learning systems, intelligent tutoring systems, automated grading and assessment tools, predictive analytics, and virtual learning environments. These technologies have the potential to personalize learning experiences, automate administrative tasks, and provide data-driven insights for decision-making. AI in education offers numerous benefits, including learner support, accessibility, and scalability. AI systems can identify each student's strengths and weaknesses, provide differentiated assessments, and ensure that all learners, regardless of their socio-economic or educational background have equitable opportunities to succeed. In the Nigerian context, where educational disparities are pronounced, AI offers promising avenues for personalized learning, automated assessments, and expanding educational reach to underserved communities.

Educational Stability

Educational stability refers to the capacity of educational institutions to maintain consistent, quality academic delivery despite systemic disruptions. This encompasses the ability to ensure continuity of learning, sustain institutional operations, and adapt to changing circumstances. Educational stability is critical for achieving the goals of tertiary education, which include contributing to national development through high-level manpower training and providing accessible and affordable quality learning opportunities. In the context of Sokoto State, educational stability is threatened by infrastructural deficits, limited resources, and administrative inefficiencies. AI technologies offer potential solutions to these challenges by enabling remote learning, automating administrative processes, and providing data-driven insights for institutional planning and decision-making.

Theoretical Framework

This study is anchored on the Digital Transformation Theory, which posits that the integration of digital technologies into all areas of an organization fundamentally changes how it operates and delivers value to its stakeholders. In the educational context, digital transformation involves the strategic adoption of technologies such as AI to enhance teaching, learning, research, and institutional management. The Digital Transformation Theory provides a useful lens for understanding AI adoption in Sokoto State's tertiary institutions. It emphasizes that technology integration is not merely about deploying new tools but involves comprehensive institutional change encompassing infrastructure, capacity building, policy frameworks, and cultural shifts. This theoretical perspective underscores the need for strategic planning and stakeholder collaboration in AI adoption.

Review of Empirical Studies

Several studies have examined AI adoption in Nigerian higher education, providing valuable insights for this research. Obasi and Ubani (2025) conducted a literature review on the integration of AI in tertiary institutions in Nigeria and its influence on learning outcomes. The review explored multifaceted perspectives on the implementation and impacts of AI in higher education, specifically within Nigerian universities. The study identified critical gaps in the current discourse, suggesting that a more robust examination of empirical data and detailed analyses of obstacles encountered during AI integration are essential. Manafa and Onyekaba (2025) examined the utilization of AI in the management of tertiary institutions in Nigeria. The paper revealed that AI, if properly utilized, can aid effective tertiary institutions administration, facilitate efficient management of data and decision-making, support resource optimization, aid implementation of teaching programmes, improve research programme development, and improve security in tertiary institutions. However, the study also identified challenges including bias and discrimination, data privacy and security breaches, lack of technical expertise and resources, power problems, and job displacement.

Agu and Agu (2025) examined the potential and challenges of implementing AI-driven learning platform systems in Nigeria's education sector to promote sustainable digital inclusion. The study identified critical barriers such as inadequate internet connectivity, limited technical capacity, data privacy concerns, and linguistic diversity, which impede widespread adoption. It also underscored opportunities for sustainable integration of AI through targeted policy formulation, capacity building, infrastructural investments, and public-private partnerships. Peters and Olojede (2025) examined AI's pros and cons in Nigerian higher education, noting that in addition to ethics and cognition, there are concerns around infrastructural deficit, access, and affordability. The study recommended critical AI literacy for lecturers and students alike, the need for an institutional AI policy that would detail the how of AI use, and the need for a robust data governance structure to safeguard institutions' data.

Suleiman (2025) investigated the effect of AI on tertiary institutions in Nigeria, focusing on Sokoto State. Using a descriptive survey design with a population of 1,612 staff across all tertiary institutions in Sokoto State, the findings revealed that personalized learning, improved management efficiency, enhanced student engagement, innovation and competitive advantage, enhanced faculty productivity, and optimized administrative processes were the effects of adopting AI. The study highlighted the need for strategic planning, infrastructure development, and capacity building to ensure effective AI adoption. Abubakar, Onasanya, Aliyu and Abdulrahman (2025) reimagined edupreneurship with AI technologies, examining pathways to modern educational excellence in Nigerian tertiary institutions. Similarly, Usman, Bello, Aliyu and Adamu (2025) examined leveraging generative AI tools in enhancing teaching, research, and assessment of learning in Nigerian tertiary institutions.

Methodology

Research Design

This study adopted a qualitative research approach. The qualitative design was deemed appropriate as it allows for an in-depth exploration of the perceptions, experiences, and insights of stakeholders regarding AI adoption in tertiary institutions.

Area of Study

The study was conducted in Sokoto State, Nigeria. Sokoto State is located in the North-Western geopolitical zone of Nigeria and has several tertiary institutions, including Sokoto State University, Shehu Shagari University of Education, Umaru Ali Shinkafi Polytechnic, and various colleges of education and health technology institutions.

Population and Sample

The population of the study comprised academic staff, administrators, and ICT officers in tertiary institutions in Sokoto State. Drawing on Suleiman's (2025) study, the total number of staff in all tertiary institutions in Sokoto State was 1,612 comprising 530 academic staff and 1,082 non-academic staff.

A purposive sampling technique was used to select participants for the study. Participants included:

i. 15 academic staff from various tertiary institutions
ii. 10 administrators (including registrars, deans, and heads of departments)
iii. 5 ICT officers
iv. 3 policymakers from the state ministry of education

The sample size was determined based on the principle of data saturation, where data collection continued until no new information emerged.

Instruments for Data Collection

Data were collected through:

i. Semi-structured interviews with academic staff, administrators, and ICT officers
ii. Document analysis of policy documents, institutional reports, and strategic plans
iii. Review of existing literature on AI adoption in Nigerian higher education

The interview guide covered themes such as awareness of AI technologies, perceived benefits and challenges of AI adoption, institutional readiness, and recommendations for effective integration.

3.5 Method of Data Analysis

Data were analyzed using thematic analysis. The analysis involved:

i. Transcribing interview recordings
ii. Coding the data to identify recurring themes
iii. Categorizing themes into broader patterns
iv. Interpreting the findings in relation to the research objectives and existing literature

Findings and Discussion

Potential of AI for Enhancing Instructional Delivery

The findings revealed that AI-driven technologies have significant potential to enhance instructional delivery in tertiary institutions in Sokoto State. Participants identified several AI applications that could transform teaching and learning:

Adaptive Learning Systems: Participants noted that adaptive learning systems can personalize the learning experience by adjusting content and pace based on individual student performance.

This is particularly relevant in the Nigerian context where overcrowded classrooms and varied student learning styles are prevalent. As one participant stated:

"AI can help us address the challenge of large class sizes by providing personalized learning pathways for each student. This would ensure that no student is left behind." (Academic Staff, SSCOE)

Automated Assessment and Feedback: AI-powered assessment tools can provide immediate feedback to students, reducing the workload on lecturers and enabling timely intervention. This aligns with the findings of Manafa and Onyekaba (2025) who noted that AI can aid implementation of teaching programmes.

Virtual Learning Platforms: The COVID-19 pandemic highlighted the importance of remote learning capabilities. AI-enhanced virtual learning platforms can support distance education and ensure learning continuity during disruptions. The findings suggest that such platforms can bridge the gap between urban and rural students by providing access to quality learning resources.

Predictive Analytics: AI can analyze student data to predict academic performance and identify at-risk students, enabling early intervention. This finding is consistent with Suleiman (2025) who found that personalized learning and enhanced student engagement were effects of adopting AI in tertiary institutions in Nigeria.

Opportunities and Challenges of AI Integration

Opportunities

The study identified several opportunities for AI integration:

Improved Administrative Efficiency: AI can automate routine administrative tasks such as student registration, timetable scheduling, and record management. This would free up staff time for more strategic activities. Manafa and Onyekaba (2025) similarly found that AI can facilitate efficient management of data and decision-making, and support resource optimization.

Enhanced Research Productivity: AI tools can support literature reviews, data analysis, and research writing, thereby enhancing research productivity. This aligns with the findings of a study on harnessing AI in higher education research in Nigeria, which indicated that AI can enhance efficiency in research processes and broaden access to global scholarship.

Expanded Access to Education: AI can make education more accessible to underserved communities through online and distance learning platforms. Agu and Agu (2025) noted that AI offers promising avenues for expanding educational reach to underserved communities.

Data-Driven Decision Making: AI analytics can provide insights for institutional planning and policy formulation. Participants noted that this is particularly important in Sokoto State where resource allocation decisions need to be evidence-based.

Challenges

Despite the opportunities, several challenges were identified:

Infrastructural Deficits: Inadequate electricity supply, limited internet connectivity, and lack of modern computing facilities were identified as major barriers. This finding is consistent with

multiple studies that have highlighted infrastructural deficits as a key challenge. One participant remarked:

"How can we talk about AI when we don't even have stable electricity or reliable internet? These are basic necessities that we lack." (ICT Officer, Umaru Ali Shinkafi Polytechnic)

Limited Digital Skills: The study found that both staff and students lack the necessary digital skills to effectively utilize AI tools. This finding corroborates the work of Peters and Olojede (2025) who noted concerns around infrastructural deficit, access, and affordability in the Nigerian educational context.

Financial Constraints: The cost of acquiring and maintaining AI infrastructure is prohibitive for many institutions in Sokoto State. This aligns with findings on the challenges of AI adoption in Nigeria.

Lack of Policy Frameworks: The absence of clear guidelines and policies for AI adoption in education was identified as a significant challenge. This finding is consistent with the work of scholars who have called for the development of ethical and regulatory frameworks for AI in Nigerian higher education.

Resistance to Change: Some staff members are resistant to adopting new technologies due to fear of job displacement or lack of familiarity with AI tools. This finding is supported by studies that have identified concerns about job displacement as a barrier to AI adoption.

Readiness of Tertiary Institutions for AI Adoption

The study assessed the readiness of tertiary institutions in Sokoto State for AI adoption across several dimensions:

Awareness: The findings revealed mixed levels of awareness. While some staff members were familiar with AI concepts and tools, others had limited knowledge. A study on awareness and utilization of Microsoft Copilot among students and staff of Sultan Abdulrahman College of Health Technology, Gwadabawa, Sokoto State, revealed that 96% of students remained unaware of Microsoft Copilot. This suggests a significant awareness gap that needs to be addressed.

Infrastructure: Most institutions lack the basic infrastructure required for AI adoption. This includes reliable electricity, high-speed internet, and modern computing facilities. The findings are consistent with broader studies on digital transformation in Nigerian universities which have identified electricity issues as a major challenge.

Human Capacity: There is a shortage of staff with the technical expertise to implement and manage AI systems. This finding is consistent with studies that have identified lack of technical expertise as a challenge.

Policy Environment: The absence of institutional and national policies on AI in education was identified as a critical gap. However, there are positive developments at the national level. The 2024 National Policy Dialogue on AI in Nigerian Higher Education produced Nigeria's first structured roadmap for integrating AI into higher education: The Draft National Higher Education AI Framework. Additionally, the National Commission for Colleges of Education (NCCE) has commenced a comprehensive review of the NCE curriculum, integrating AI and emerging technology standards.

Leadership and Vision: The study found that leadership commitment is crucial for AI adoption. Institutions with proactive leadership that prioritizes technology integration are more likely to make progress in AI adoption. This is consistent with the call for strategic institutional planning for AI integration.

Strategic Framework for AI Adoption

Based on the findings, the study proposes a strategic framework for AI adoption in tertiary institutions in Sokoto State:

1. **Infrastructure Development**: Investment in digital infrastructure, including reliable electricity, high-speed internet, and modern computing facilities, is a prerequisite for AI adoption. This aligns with recommendations from multiple studies.
2. **Capacity Building**: Training programmes should be developed to enhance the digital skills of staff and students. This includes AI literacy programmes, technical training for ICT staff, and pedagogical training for academic staff on integrating AI into teaching.
3. **Policy Formulation**: Clear guidelines and policies should be developed to guide AI adoption. This includes institutional AI policies, ethical guidelines, data governance frameworks, and standards for AI use in teaching, learning, and research.
4. **Stakeholder Collaboration**: Partnerships between institutions, government agencies, private sector organizations, and development partners should be established to support AI adoption. Public-private partnerships are key to preserving the sustainability of the education sector.
5. **Phased Implementation**: AI adoption should be implemented in phases, starting with pilot programmes and gradually scaling up based on lessons learned. This approach allows institutions to build capacity and address challenges incrementally.
6. **Monitoring and Evaluation**: Mechanisms should be established to monitor and evaluate the impact of AI adoption on educational outcomes. This includes tracking student performance, staff productivity, and institutional efficiency.

Conclusion

This study examined the strategic adoption of Artificial Intelligence for enhancing educational stability in tertiary institutions in Sokoto State, Nigeria. The findings indicate that AI has significant potential to enhance instructional delivery, student engagement, and institutional management. AI-driven technologies such as adaptive learning systems, automated administrative processes, predictive analytics, and virtual learning platforms can support effective teaching, learning continuity, and data-driven decision-making. However, the successful implementation of AI depends on addressing several challenges, including infrastructural deficits, limited digital skills, financial constraints, and the absence of supportive policy frameworks. Institutional readiness for AI adoption varies across dimensions such as awareness, infrastructure, human capacity, policy environment, and leadership commitment. The study concludes that a well-structured and context-specific AI adoption strategy can promote educational stability by reducing disruptions, improving access to learning, and fostering innovation. Such a strategy must be comprehensive, addressing not only technological requirements but also human capacity, policy frameworks, and institutional culture.

Recommendations

Based on the findings, the following recommendations are made:

1. **Investment in Digital Infrastructure**: The Sokoto State Government should increase funding for digital infrastructure in tertiary institutions, including reliable electricity, high-speed internet, and modern computing facilities. This is essential for creating an enabling environment for AI adoption.
2. **Staff Training and Development**: Tertiary institutions should develop comprehensive training programmes to enhance the digital skills of academic and non-academic staff. This includes AI literacy, technical training, and pedagogical training on integrating AI into teaching and learning.
3. **Development of AI Policies**: The Sokoto State Ministry of Education, in collaboration with tertiary institutions, should develop clear guidelines and policies for AI adoption. This should include institutional AI policies, ethical guidelines, data governance frameworks, and standards for AI use.
4. **Curriculum Review**: Tertiary institutions should review their curricula to integrate AI and emerging technologies. This aligns with the NCCE's ongoing review of the NCE curriculum to embed AI awareness and digital competencies.
5. **Stakeholder Collaboration**: Partnerships should be established between institutions, government agencies, private sector organizations, and development partners to support AI adoption. Public-private partnerships are key to mobilizing resources and expertise.
6. **Phased Implementation**: AI adoption should be implemented in phases, starting with pilot programmes in selected institutions or departments. This allows for learning, adaptation, and capacity building before scaling up.
7. **Monitoring and Evaluation**: Mechanisms should be established to monitor and evaluate the impact of AI adoption on educational outcomes. This will inform continuous improvement and ensure that AI investments deliver desired results.

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INTEGRATING EDUCATIONAL TECHNOLOGY IN TECHNICAL AND VOCATIONAL EDUCATION: A CATALYST FOR SUSTAINABLE NATIONAL DEVELOPMENT

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Abstract

This paper examines the role of educational technology in strengthening technical and vocational education as a pathway to sustainable national development in Nigeria. The purpose is to interrogate how the structure and delivery of training for aspiring engineers can be enhanced through the systematic integration of technological tools and instructional strategies. Adopting a conceptual and analytical approach, the study draws on existing literature and theoretical perspectives to explore the interconnections between educational technology, vocational education, and technical training systems. The central argument advanced is that effective integration of educational technology transforms instructional processes by fostering interactive, learner centred environments that enhance innovative thinking, problem solving, and productivity. It further contends that the alignment of instructional materials, methods, and learning contexts is essential for developing relevant technical competencies and supporting indigenous technological advancement. The paper contributes to knowledge by offering a synthesised perspective that links educational technology with skill development and sustainable outcomes. It provides a conceptual basis for rethinking instructional design and policy direction within technical education, while highlighting the need for coordinated, technology driven reforms to address persistent developmental challenges.

Keywords: Educational Technology, Technical and Vocational Education, Indigenous Technology Development, Sustainable Development and Innovation and Productivity

Introduction

The rapid transformation of global economies in the twenty-first century has placed education at the centre of national development discourse, particularly with respect to how technology is harnessed to equip learners with relevant, future-ready competencies. Information and communication technology (ICT) has been applied in education for over a century, but it is the deployment of digital technology over the past four decades that holds the most significant potential to transform teaching and learning. Educational technology, broadly understood, refers to the use of tools, technologies, processes, procedures, resources, and strategies to improve learning experiences (Huang et al., as cited in Scheffel & Wirth, 2022). This encompasses a continuum of innovations from smart boards and learning management systems to artificial intelligence-driven tutoring platforms all aimed at enhancing instructional delivery and educational outcomes.

Technical and Vocational Education (TVE), on the other hand, constitutes a distinct and purposeful dimension of educational provision. It is broadly defined as the component of education that equips

individuals with occupational knowledge, practical skills, and attitudes essential for productive engagement in specific trades, industries, and professions. UNESCO (2022) has called for transforming TVET for successful and just transitions, recognising it as a critical lever for socioeconomic advancement. Within the vocational training domain, TVE encompasses structured preparation in applied technical disciplines including civil, electrical, mechanical, and electronic vocation that form the backbone of industrialisation and infrastructural development. In Nigeria, TVE occupies a constitutionally recognised yet systemically neglected space within the educational architecture. Technical and Vocational Education and Training (TVET) is a vital component of Nigeria's educational system, designed to equip students with practical skills for employability and economic growth. Notwithstanding its strategic importance, technical colleges in Nigeria suffer neglect by government, especially in the areas of skilled manpower, infrastructure, funding, and societal stigmatisation. This neglect has constrained the sector's capacity to respond adequately to the nation's growing labour market demands.

The deployment of educational technology within TVE presents a transformative opportunity to address these systemic deficiencies. Research highlights digital integration's potential to expand educational access, support multimedia-rich learning, enable personalised approaches, and enhance system resilience during crises. Yet, the digital divide remains a formidable obstacle, only 35% of Nigerian vocational institutions have reliable access to digital tools (National Bureau of Statistics, 2023), contrasting sharply with Europe, where over 80% of schools utilise digital platforms. Sustainable national development defined as development that meets present needs without compromising the capacity of future generations is contingent on the productive capacity of the citizenry. With rapid advancements in technology and increasing focus on sustainability, vocational training in Nigeria must evolve to incorporate digital and green skills, which are essential for ensuring long-term national competitiveness (Ejikpese & Effiom, 2024). Despite the widely acknowledged strategic importance of Technical and Vocational Education (TVE) to Nigeria's socioeconomic development, the sector continues to grapple with deep-seated deficiencies that undermine its effectiveness. Infrastructural deficiencies, unreliable electricity supply, and insufficient professional development significantly limit effective adoption of educational technology among Nigerian teachers (Adeleke & Emechebe, 2025).

Compounding this, numerous structural and systemic challenges hinder effective implementation, including the absence of localised digital content, inadequate funding, limited stakeholder collaboration, and persistent resistance to change (Oyelere et al., 2022; Owan et al., 2023). These conditions have produced a sector ill-equipped to leverage technology as a transformative tool. Furthermore, while there exists a high level of awareness and generally positive attitudes toward technology among Nigerian TVET students and teachers, this enthusiasm does not consistently translate into readiness, mainly due to limited digital literacy and the absence of structured capacity-building programmes (Bakare et al., 2023; Ukeje et al., 2024), The gap between policy intent and practical implementation remains wide. There is, therefore, an urgent need to critically examine how educational technology can be systematically and effectively integrated into TVE to serve as a genuine catalyst for sustainable national development in Nigeria.

Purpose of the Study

The purpose of this study is to examine the extent to which educational technology is integrated into Technical and Vocational Education in Nigeria, and to explore its implications for sustainable national development.

Research Question

The following research questions guided this study:

1. What is the current state of educational technology integration in Technical and Vocational Education institutions in Nigeria, and what barriers hinder its effective adoption?
2. How do TVE educators and students perceive the role of educational technology in enhancing skill acquisition and promoting sustainable national development in Nigeria?
3. What strategies can be adopted to optimise the integration of educational technology in Technical and Vocational Education for sustainable national development in Nigeria?

Conceptual Review

Educational technology (EdTech) is a concept whose meaning has evolved considerably through decades of scholarly debate and technological advancement. The 2023 UNESCO Global Education Monitoring Report recognises that technology affects education across five channels: as an input, a means of delivery, a skill, a tool for planning, and a social and cultural context. More comprehensively, educational technologies refer to the set of digital tools, resources, applications, and methodologies used to facilitate the teaching-learning process, encompassing software, online platforms, hardware devices such as tablets, computers, and interactive whiteboards, and assistive technologies all aimed at improving access to education, personalising learning paths, and fostering dynamic interaction between students and teachers. The Association for Educational Communications and Technology (AECT) further refined this understanding in its 2023 revision, reflecting educational technology as both a process and a product, accessible to practitioners and researchers navigating the rapidly evolving digital educational landscape.

It is, however, important to adopt a critical stance here. The expansive definition of educational technology risks obscuring a fundamental distinction between access to tools and meaningful pedagogical integration. Possessing digital infrastructure does not automatically translate to improved learning outcomes. The adoption of digital technology has resulted in many changes in education and learning, yet it is debatable whether technology has transformed education as many claim, particularly given that its application varies significantly by community, socioeconomic level, teacher willingness, and country income. This caveat is especially pertinent in Nigeria's TVE context, where the conflation of hardware provision with educational transformation remains a recurring policy error.

Technical and Vocational Education (TVE) constitutes a structured mode of educational provision designed to develop occupational competencies cognitive, psychomotor, and attitudinal for productive engagement in skilled trades, industries, and professions. The objective of TVET is to provide individuals with the skills and qualifications required to enter the workforce or to enhance

their existing skills for better job opportunities, and training may come in the form of apprenticeships, vocational schools, on-the-job training, and other forms of hands-on learning. In Nigeria, TVE is administered at technical colleges, polytechnics, and universities of technology and is governed by the National Board for Technical Education (NBTE).

Despite this institutional framework, the Nigerian TVE sector is characterised by persistent systemic weaknesses. Nigeria's 2025 education budget received only 7.08% of total national expenditure, falling short of both the 2024 allocation of 8.21% and UNESCO's recommended benchmark of 15–20%. This chronic underfunding has perpetuated infrastructural decay and a growing disconnect between TVET curricula and the demands of industry. Empirical evidence reveals that 80% of TVET graduates themselves disagreed that the curriculum equipped them with everything needed for productive employment, a damning indictment of a system that remains theoretically oriented in a domain that demands practical mastery. The position taken here is unequivocal: without deliberate reform that centres technological integration within curriculum design and instructional delivery, Nigerian TVE will continue to produce graduates ill-prepared for the twenty-first-century labour market.

Vocational education within the TVET framework encompasses applied training in disciplines such as civil, mechanical, electrical, and electronic vocation. The development of technical skills in these fields requires instructional environments that closely replicate real-world industry scenarios an aspiration that conventional pedagogies have long struggled to fulfil. The use of virtual reality in vocational education and training not only improves technical skills but also provides a space for the formation of professional attitudes through scenarios that simulate real challenges, helping students make accurate decisions and act under realistic conditions. There is a lack of infrastructure and policy implications for the inclusion of innovative technologies in TVET in Nigeria, underscoring the dire need to improve policy, curriculum development, and government interventions (Adeagbo et al., 2024). The gap between the technological aspirations of Vocational education globally and the material realities of Nigerian technical colleges is not merely logistical it is a governance failure that demands urgent policy redress.

Sustainable national development, in the Brundtland tradition, denotes development that meets present needs without compromising the capacity of future generations to meet theirs. In Nigeria's context, this imperative is inextricably linked to human capital formation and the productive capacity of the citizenry. Nigeria's economy grew at an average annual rate of 3.7% in 2023–2024 with a GDP of $242 billion, yet over 46% of its population lives in poverty a paradox that exposes the inadequacy of growth without inclusive skills development. Adoption of TVET in Nigeria is imperative because of its potentials for poverty reduction, economic recovery, and sustainable development, with human capital development serving as critical to technical progress, social development, and a culture of self-reliance and self-employment. Sustainable development cannot, therefore, be decoupled from the quality and technological orientation of vocational training.

The relationship between educational technology and vocational training is not merely complementary it is constitutive. Skills for technology-oriented trades are best acquired in a high-tech learning environment; thus, for technical colleges to remain relevant and attractive, they must identify and introduce digital skills and competencies for the changing world of work, utilising opportunities provided by digitalisation to enhance their core objectives. This position challenges

the passive framing of technology as an add-on to TVE and repositions it as a structural prerequisite. The demands for modern work-related, entrepreneurial, and self-reliant skills in the twenty-first century make single-discipline approaches insufficient; effective STEM and TVET collaboration is essential for producing graduates with functional and comprehensive competencies (Okon et al., 2024).

Among the most significant technology-driven instructional innovations in TVET are simulation-based learning, blended learning, and virtual reality (VR) environments. Virtual reality technology provides students with intuitive and vivid learning scenarios and abundant interactive resources, and studies find that it significantly improves students' mastery of theoretical knowledge and proficiency in practical skills, while enhancing their satisfaction and interest in learning. However, the same evidence notes that high equipment costs and insufficient specialised teaching resources remain limitations, constraints that are vastly amplified in resource-constrained contexts like Nigeria.

Blended learning, as a pedagogical strategy, gives students exposure to both in-person and online educational environments; it is a learner-centred approach that ensures instructions are delivered effectively and enables students to learn whenever and wherever they want (Islam et al., 2022; Eze, 2023). Such flexibility holds considerable promise for Nigeria's geographically dispersed TVET population. Nevertheless, the uncritical adoption of Western-designed instructional platforms without contextualisation to Nigeria's linguistic, infrastructural, and cultural realities represents a persistent risk.

The challenges confronting Nigerian TVET are multidimensional and mutually reinforcing. Infrastructural deficiencies, unreliable electricity supply, and insufficient professional development significantly limit effective adoption of educational technology, even among teachers who demonstrate positive perceptions of digital tools (Adeleke & Emechebe, 2025). Numerous structural and systemic barriers hinder AI and digital technology implementation, including the absence of localised content, inadequate funding, limited stakeholder collaboration, and persistent resistance to change, with many institutions still lacking coherent digital strategies to guide integration efforts (Oyelere et al., 2022; Owan et al., 2023). Teachers' limited confidence in technical skills may hinder effective classroom integration despite their positive attitudes toward educational technology, suggesting that attitudinal readiness alone is insufficient without structural support. Only 35% of Nigerian vocational institutions have reliable access to digital tools (National Bureau of Statistics, 2023), rendering the discourse on technology-driven TVET reform largely aspirational in the absence of a coherent national digital infrastructure policy. This study contends that addressing these challenges requires not incremental adjustments but a paradigm shift one that places educational technology at the systemic core of TVE reform as a deliberate strategy for sustainable national development

Theoretical Framework

The theoretical framework underpinning this study is anchored on four interconnected theories namely Constructivist Learning Theory, Systems Theory, the Technological Pedagogical Content Knowledge (TPACK) Framework, and Human Capital Theory. These theories were selected because each explains a critical dimension of how educational technology can strengthen

Technical and Vocational Education (TVE) and contribute to sustainable national development in Nigeria. The integration of these theories provides a multidimensional understanding of learner engagement, teacher competence, institutional coordination, and national productivity. Rather than functioning independently, the theories collectively establish a comprehensive explanatory basis for understanding technology integration within technical and vocational education.

Constructivist Learning Theory, associated with the works of Jean Piaget and Lev Vygotsky, posits that learning occurs through active engagement, interaction, and the construction of knowledge from experience rather than through passive reception of information (Piaget, 1972; Vygotsky, 1978). The theory emphasises learner centred instruction where students develop understanding through exploration, collaboration, and problem solving. Within the context of educational technology, constructivism supports the integration of digital learning tools, simulations, virtual laboratories, and interactive platforms that enable learners to engage with instructional content at their own pace while developing practical competencies. This perspective is particularly relevant to TVE because technical and vocational education relies heavily on experiential learning and the acquisition of practical skills required for industrial productivity and technological innovation.

The relevance of constructivism to this study lies in its emphasis on active learning environments that foster creativity, innovation, and critical thinking. Educational technology enhances these processes by providing opportunities for adaptive learning, collaborative engagement, and real world problem solving. Through digital tools and technology enhanced instructional strategies, learners are better positioned to develop technical competencies that align with contemporary workforce demands. Nevertheless, constructivist theory has been criticised for assuming the availability of supportive learning environments and adequate instructional resources, conditions that remain limited in many Nigerian technical institutions (Kirschner, Sweller & Clark, 2006). Inadequate infrastructure, limited access to digital facilities, and insufficient teacher preparation may constrain the practical implementation of constructivist pedagogy in Nigeria. Despite these limitations, the theory remains significant because it provides a normative framework for evaluating the quality and effectiveness of technology enhanced teaching and learning within TVE institutions.

Systems Theory, originally developed by Ludwig von Bertalanffy (1968), provides another important foundation for this study. The theory views institutions as interconnected systems in which all components operate interdependently to achieve collective goals. In educational contexts, Systems Theory explains how changes in one aspect of the educational structure affect other components such as curriculum, teaching practices, administration, funding, infrastructure, and policy implementation. This perspective is particularly important in understanding the integration of educational technology into Nigerian TVE because successful technology adoption requires coordination across multiple institutional and policy dimensions.

The application of Systems Theory to this study highlights the inadequacy of fragmented approaches to educational technology integration. In many Nigerian technical institutions, educational reforms often focus on the procurement of technological equipment without corresponding investment in teacher training, curriculum redesign, maintenance systems, or institutional policy development. Such isolated interventions frequently result in ineffective utilisation of educational technologies. Systems Theory therefore suggests that meaningful

educational transformation can only occur when reforms are approached holistically, with all educational subsystems functioning collaboratively (Banathy, 1991). However, critics of Systems Theory argue that the theory sometimes prioritises institutional stability and equilibrium at the expense of transformative change and innovation. Despite this limitation, the theory remains relevant because it underscores the need for coordinated and systemic educational reforms capable of supporting sustainable technological integration within TVE.

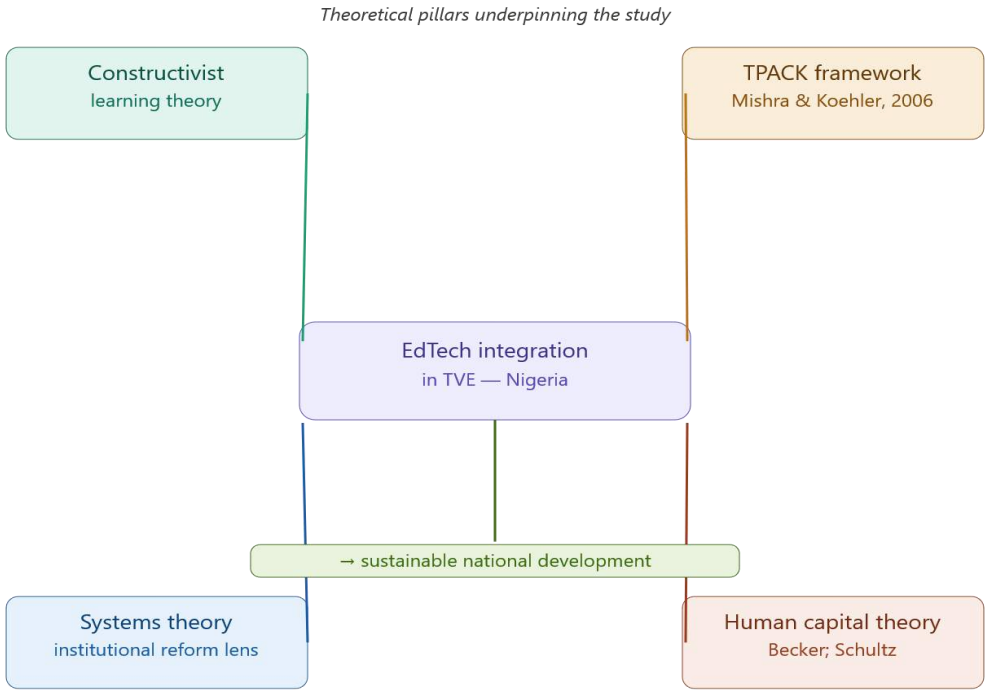
The Technological Pedagogical Content Knowledge (TPACK) Framework developed by Mishra and Koehler (2006) further strengthens the theoretical basis of this study. The framework argues that effective teaching with technology requires the integration of three essential forms of knowledge namely technological knowledge, pedagogical knowledge, and content knowledge. According to the framework, teachers must possess the ability to combine these knowledge domains effectively in order to facilitate meaningful learning experiences. The TPACK framework is particularly applicable to technical and vocational education because many technical subjects involve abstract concepts and practical demonstrations that require appropriate technological tools and instructional approaches for effective delivery.

The relevance of TPACK to this study lies in its ability to explain why educational technology integration often fails within Nigerian TVE institutions. In many cases, teachers may possess adequate subject knowledge but lack the technological competence or pedagogical skills necessary to integrate digital tools effectively into classroom instruction. Consequently, educational technologies are underutilised or applied superficially without improving learning outcomes. TPACK therefore provides a useful analytical lens for examining teacher preparedness and instructional effectiveness in technology enhanced technical education. Nonetheless, scholars have argued that the framework pays insufficient attention to contextual, ethical, and sociocultural factors influencing technology integration (Angeli & Valanides, 2009). This limitation is particularly important within the Nigerian context where infrastructural inequalities and socio economic disparities significantly affect technology adoption. Despite these criticisms, the framework remains valuable because it highlights the central role of teacher competence in the successful implementation of educational technology.

Human Capital Theory, associated with Theodore Schultz (1961) and Gary Becker (1964), constitutes the final theoretical foundation of this study. The theory posits that investment in education, training, and skill acquisition enhances human productivity and contributes to economic growth and national development. Human Capital Theory views education as a strategic investment capable of improving labour efficiency, reducing unemployment, and increasing national competitiveness. Within the Nigerian context, the theory is highly relevant because technical and vocational education is expected to produce a skilled workforce capable of supporting industrialisation, innovation, and sustainable development.

The integration of educational technology into TVE aligns with the assumptions of Human Capital Theory because digital technologies improve instructional quality, facilitate skills acquisition, and prepare learners for participation in technologically driven economies. Through effective technology integration, students acquire practical and innovative competencies that enhance employability and national productivity. However, critics of Human Capital Theory argue that the theory tends to reduce education to economic outcomes while neglecting its social and humanistic

dimensions (Marginson, 2019). Despite this criticism, the theory remains relevant to this study because it provides a strong justification for investing in educational technology as a means of strengthening technical capacity and promoting sustainable national development in Nigeria.



Collectively, these theories operate at complementary levels of analysis. Constructivist Learning Theory explains learning processes at the learner level, TPACK addresses teacher competence and instructional delivery, Systems Theory focuses on institutional coordination and policy integration, while Human Capital Theory emphasises national development and economic productivity. Their convergence reinforces the argument that educational technology should not be viewed merely as a supplementary instructional tool but as a strategic mechanism for transforming technical and vocational education and advancing sustainable national development in Nigeria.

Methodology

This study adopts a conceptual and analytical research design. Rather than generating primary empirical data through fieldwork, the study systematically examines, synthesises, and critically interrogates existing theoretical frameworks, policy documents, empirical studies, and scholarly literature related to educational technology integration in Technical and Vocational Education (TVE) and its implications for sustainable national development in Nigeria. This design is appropriate given that the study's primary objective is to establish conceptual clarity, identify structural patterns, and construct a theoretically grounded argument rather than to test hypotheses through quantitative or qualitative data collection. The study relies exclusively on secondary data sources**.** These include peer-reviewed journal articles, institutional policy reports, UNESCO and World Bank documents, national education statistics, and relevant government publications spanning the period 2016–2025, with emphasis on the most recent literature from 2022 onwards.

Sources were retrieved from reputable academic databases including Google Scholar, ResearchGate, JSTOR, and ERIC, as well as official portals of the National Board for Technical Education (NBTE), UNESCO-UNEVOC, and the National Bureau of Statistics Nigeria. Selection criteria prioritised recency, scholarly credibility, contextual relevance to Nigeria, and alignment with the study's thematic concerns.The study employs critical content analysis and thematic synthesis as its primary analytical methods. Relevant literature was systematically reviewed, coded thematically, and interrogated for convergences, contradictions, and gaps. Arguments were constructed deductively from established theoretical frameworks, Constructivist Learning Theory, Systems Theory, TPACK, and Human Capital Theory and tested against empirical evidence drawn from the reviewed literature. This dual movement between theory and evidence constitutes the analytical core of the study. A conceptual and analytical approach is approppriate because the subject of educational technology integration in Nigerian TVE remains undertheorised, necessitating conceptual groundwork before empirical investigation. Also the significant gaps exist in the coherence of existing policy frameworks, which conceptual analysis is uniquely positioned to expose and address. Torraco (2016) argues, that well-constructed conceptual study generate the theoretical foundations upon which subsequent empirical research is built, making them indispensable to scholarly and policy discourse.

Educational Technology and the Transformation of Technical Training

The proposition that digital instructional tools transform technical training is now sufficiently evidenced in the literature to be regarded as settled the more urgent scholarly task is to interrogate how, under what conditions, and for whom this transformation is achievable. As Badarudin et al. (2024) assert, TVET, as the foundation for training skilled talents, must continually integrate digital technology deeply into education methods and content to provide better vocational skills training for workers, enhancing their employability and adaptability. Yet this imperative, though theoretically sound, glosses over a structural reality in Nigeria's TVE landscape: digital tools cannot transform training environments that lack the preconditions for their use. The deployment of interactive whiteboards, computer-aided design (CAD) software, and digital learning management systems in technical and vocational classrooms presupposes electricity reliability, internet connectivity, institutional capacity, and digitally competent instructors all of which remain deeply uneven across Nigeria's technical institutions (Adeleke & Emechebe, 2025; Owan et al., 2023). The discourse on digital instructional tools must therefore shift from celebration to critical contextualisation, insisting that technology adoption without systemic support is not transformation but simulation of it.

Furthermore, the shift from teacher centred to learner centred instruction represents one of the most significant pedagogical reorientations in contemporary TVE discourse. UNESCO-UNEVOC (2022) affirms that to prepare learners to function effectively in today's digitalised workplace and digital society, TVET teachers and trainers need to apply new pedagogical approaches, instructional tools, and educational technologies to deliver learner-centred, future oriented teaching and training. Learner centred approaches facilitated by technology, including collaborative problem-solving platforms, gamified learning environments, and adaptive tutoring systems, align strongly with constructivist principles and have demonstrated positive outcomes in student engagement and skill retention (Mohanty, 2023). However, learner-centred environments created by technology are not inherently equitable. As the UNESCO Global Education Monitoring

Report (2023) cautions, the absence of evidence of technology's impact on learning does not necessarily equal evidence of absence, but focusing on test scores alone is an insufficient measure of student learning in its fuller sense. In Nigeria's TVE context, where learners are often first-generation technology users navigating significant socioeconomic inequalities, implementing learner-centred digital environments without corresponding digital literacy development risks compounding existing disadvantages rather than dissolving them (Oyelere et al., 2022).

Perhaps the most compelling case for EdTech integration in TVE lies in simulation and virtual laboratory environments, which offer cost-effective, risk-free alternatives to physical practical training. May et al. (2023) assert that virtual laboratories provide immersive and interactive environments where students can manipulate variables, observe outcomes, and test hypotheses in real time, and empirical studies indicate that virtual lab-based learning significantly improves students' conceptual understanding and scientific reasoning compared to traditional instruction. A 2024 meta-analysis by Li et al. of virtual laboratories in vocational education further validated these outcomes, confirming their effectiveness across multiple engineering disciplines. Negahban (2024) further notes that virtual experimentation presents a simulation or emulation of a physical lab, allowing students to interact with virtual equipment and materials and conduct lab experiments in a technology-mediated manner a particularly attractive proposition for Nigerian technical colleges whose physical laboratories remain chronically under-equipped (Adeagbo et al., 2024). Yet this study resists uncritical optimism. Simulation environments cannot fully replicate the tactile, material complexity of real-world engineering practice. The risk of substituting virtual competence for genuine practical mastery is real, and this risk intensifies when virtual labs are adopted as budget-saving measures rather than as pedagogical innovations (Negahban, 2024).

Moreso there is a growing body of evidence linking EdTech integration to enhanced problem-solving abilities in technical learners. Mohanty (2023) demonstrates that collaborative problem-solving and knowledge co-construction through augmented reality enhance student engagement and comprehension, while AI-driven adaptive systems allow personalised learning paths that target individual skill deficits (Mahmudi et al., 2023; Wu & Yu, 2024). The development of higher-order thinking analysis, synthesis, and application is, after all, the ultimate objective of technical education, not the reproduction of standardised procedural responses. However, the evidence base for technology-driven problem-solving gains remains predominantly generated in high-income, well-resourced educational contexts. Its transferability to Nigeria's TVE environment, where institutional capacity is severely constrained, must be theorised carefully rather than assumed (UNESCO, 2023).

Badarudin et al. (2024) assert that integrating digital tools and technology into TVET allows learners to interact with advanced tools and equipment used in real workplaces, providing businesses with more and better technical talent and facilitating industrial upgrading and transformation. This productivity-enhancement argument carries considerable policy weight in Nigeria, where skills mismatch between TVET output and industry demand continues to suppress economic productivity (Ayoola, 2023). However, productivity gains attributable to EdTech are contingent on the quality of integration not merely its occurrence. A technically trained graduate who has interacted with advanced simulation software but has never operated real industry-grade equipment represents a productivity gap, not a gain. The study therefore argues that EdTech

integration must be deliberately designed to bridge, not widen, the gap between the training environment and the world of work.

Educational Technology, Technical Competencies, and Sustainable Development

The most immediate expectation placed upon Nigerian TVE is the production of employable graduates a demand that existing evidence suggests the system has largely failed to meet. Akanbi (2023) observes that technical colleges are institutions established to produce a workforce for national development, enabling students to acquire relevant skills to be self-reliant and fit into the twenty-first-century workplace, with the view to checking the unemployment rate. Yet empirical evidence reveals that 80% of TVET graduates disagreed that the curriculum equipped them with everything needed for productive employment (Ogunode et al., 2022), exposing a profound misalignment between institutional output and labour market demands. Educational technology, deployed strategically, offers a credible pathway to closing this gap by exposing students to industry-standard digital tools, current engineering software, and real-world simulated scenarios that bring training environments closer to employer expectations (Badarudin et al., 2024; Toyo et al., 2024). This study holds that without EdTech integration as a structural feature of curriculum design, Nigerian TVE will continue to produce technically qualified but industrially irrelevant graduates.

A dimension frequently undervalued in the Nigerian EdTech-TVE discourse is the imperative of indigenous technological advancement the development of homegrown technological capacity rather than the perpetual importation of foreign solutions. David and Daniels (2024) argue that integrating sustainability practices into the TVET curriculum can enhance local technological capabilities, which are conducive to the development and deployment of renewable energy technologies, underpinning Nigeria's broader energy transition goals. This framing reorients the discussion: EdTech in TVE is not merely about teaching students to use existing technologies but about cultivating the innovative capacity to develop context-appropriate technological solutions. Nigeria's ambition for technological sovereignty demands a TVE system that produces not only technicians but innovators and this requires a pedagogical environment where digital tools are used for creation, not merely consumption (Okon et al., 2024).

Additionally, TVET graduates in Nigeria and Kenya have better job prospects largely due to their job-ready skills, and employers today prioritise individuals with specific, applicable skills that TVET provides, particularly in fields such as engineering and information technology (African Development Bank, 2023). However, employability alone is insufficient for economic sustainability. Nigeria requires a productive workforce capable not only of filling existing roles but of generating new industries, improving processes, and responding to technological disruptions. As Aspyee (2023) notes, TVET is a mechanism that could help improve the quality of the workforce by humanising its mobility, adaptability, and productivity, indirectly contributing to the enhancement of firms' competitiveness in the globalised world. Educational technology serves as the critical enabler of this ambition it is the infrastructure through which TVE graduates encounter, engage with, and eventually contribute to the knowledge economy (Ejikpese & Effiom, 2024).

Conversly the argument that TVET constitutes a direct pathway to national development is not novel, but it gains renewed urgency in the Nigerian context. TheCable (2025) reports that in 2025, the federal government launched a renewed TVET programme to promote skills that match labour market needs and reduce youth unemployment, prioritising 25 trade areas including automotive technology, welding, solar installation, and digital media signalling an emerging policy consciousness about the sector's developmental potential. Yet, as this study argues, policy declarations without institutional follow-through are historically recurrent in Nigeria's education governance (Edugist, 2026). The decisive variable is not the existence of reform programmes but the depth and sustainability of their implementation and this is precisely where EdTech integration becomes a litmus test. If digital infrastructure, teacher training, and curriculum reform do not accompany policy commitments, TVET's developmental promise will remain, as it has, unrealised (Bakare et al., 2023; Ukeje et al., 2024).

Policy Implications and Reform Strategies

Curriculum reform constitutes the foundational policy intervention required for EdTech integration to produce sustainable outcomes in Nigerian TVE. TheCable (2025) reports that the 2025 senior secondary curriculum reform streamlined trade subjects and redefined core subjects to introduce digital and vocational skills, marking a deliberate effort to align educational content with labour market demands. This is a necessary but insufficient step. Curriculum reform that introduces digital content without corresponding reform of pedagogical approach shifting from rote instruction to inquiry-based, problem-solving, and collaborative learning will merely recostume an outdated system in digital clothing. This study contends that TVE curriculum reform must be driven by industry intelligence, regularly reviewed against labour market shifts, and explicitly structured to embed EdTech not as a subject but as a pedagogical mode across all technical disciplines (Okon et al., 2024).

Similarly, teacher capacity is the most consistently identified bottleneck in EdTech integration across Sub-Saharan Africa. Badarudin et al. (2024) assert that TVET teachers need not only to master the ability to use digital technology and resources for remote teaching, but also to possess digital literacy and digital competence relevant to different professional fields and workplaces, integrating digital tools and technology into TVET and allowing learners to interact with advanced tools used in real workplaces. In Nigeria, this requirement remains largely unmet. Adeleke and Emechebe (2025) empirically confirm that infrastructural deficiencies, unreliable electricity supply, and insufficient professional development significantly limit effective adoption of educational technology, even among teachers who demonstrate positive perceptions of digital tools. The implication is clear: attitudinal readiness is necessary but structurally insufficient without sustained, institutionalised professional development programmes (UNESCO-UNEVOC, 2022). Pre-service teacher education in Nigerian TVE institutions must embed digital pedagogy as a core competency, not an elective supplement.

Also, Physical and digital infrastructure constitutes the material precondition for any meaningful EdTech reform. The Federal Ministry of Education (2025) reports that only 134 technical colleges currently exist out of more than 15,000 secondary schools in Nigeria, underscoring the urgency of comprehensive structural reform and the need for a dedicated National TVET Fund to ensure long-term sustainability. The absence of adequate hardware, internet connectivity, electricity, and

technical support renders even the most well-designed EdTech policies unimplementable (National Bureau of Statistics, 2023). Policy must therefore foreground infrastructure as a prerequisite, not a corollary, of technology-driven TVE reform. Without deliberate investment in power infrastructure, broadband connectivity, and institution-level technical support systems, curriculum reform and teacher training programmes will lack the operational environment necessary for their success (Adeagbo et al., 2024).The scale of infrastructure and capacity investment required for genuine TVE transformation exceeds the capacity of the Nigerian federal government alone. Akwang and Udoh (2024, as cited in Discover Global Society, 2025) document that targeted government training schemes and emerging public-private partnerships in Lagos and Abuja, documented between 2021 and 2024, demonstrate measurable progress, particularly in teacher professional-development coverage. However, Edugist (2026) cautions that many well-intentioned education interventions in Nigeria have struggled to move beyond pilot phases or have been weakened by bureaucratic inefficiencies, and what has often been missing is continuity, accountability, and measurable impact. This study argues that public-private partnerships must be structured around binding accountability frameworks not goodwill declarations with industry partners assuming genuine curriculum co-ownership, infrastructure investment obligations, and employment uptake commitments for TVET graduates.

Ultimately, sustainable EdTech integration in Nigerian TVE demands a coherent, long-term national policy architecture not fragmented, project-based interventions. UNESCO-UNEVOC (2022) affirms that TVET institutions' success in harnessing the benefits and tackling the challenges of digitalisation depends largely on the digital capabilities of TVET teachers and trainers, requiring governments and institutions to invest strategically in digital skills development. Policy must operationalise this imperative through enforceable minimum digital standards for TVE institutions, dedicated EdTech funding streams, and institutionalised monitoring mechanisms that hold institutions accountable for integration outcomes (NBTE, 2025; Owan et al., 2023). This study's position is unambiguous: integrating educational technology in Nigerian TVE is not an optional enhancement it is a structural necessity for any credible national development agenda in the twenty-first century.

Discussion of Key Issues

The analytical outcome of this study produces a conclusion that is both theoretically grounded and empirically defensible: educational technology integration in Nigeria's Technical and Vocational Education sector is a structural imperative whose continued marginalisation constitutes a compounding liability against the nation's sustainable development ambitions. Three guiding research questions anchored the inquiry, and their synthesis exposes a deeply entrenched contradiction a sector assigned constitutional importance and developmental centrality, yet denied the technological, financial, and institutional conditions necessary for its transformation.

On the first research question concerning the current state and barriers of EdTech integration, the analytical outcome is unambiguous. TVET faces persistent challenges including skill gaps, curriculum limitations, institutional barriers, and prevalent perception issues that collectively undermine its quality and employability outcomes (Zakiyudin & Hasim, 2025). These challenges are not disaggregated they are mutually reinforcing. Inadequate infrastructure suppresses digital adoption; digital non-adoption perpetuates curriculum irrelevance; curriculum irrelevance

produces unemployable graduates; unemployable graduates erode public confidence in TVET and the cycle continues, unbroken by policy declarations that lack implementation architecture. To transform Nigeria's education system through technology requires more than vision it demands sustained investment and coherent policy frameworks that prioritise digital infrastructure, teacher training, curriculum reform, and monitoring and evaluation (Edugist, 2026). Nigeria has not yet demonstrated this coherence.

On the second research question stakeholder perceptions of EdTech's role the study finds that attitudinal readiness among Nigerian TVE educators significantly outpaces institutional enablement. Teachers recognise the transformative potential of digital tools but operate within environments that systematically frustrate their deployment (Adeleke & Emechebe, 2025; Eke, 2024). This study's position is clear: attitudinal surveys that confirm positive perceptions while ignoring structural incapacitation are analytically insufficient and policy misleading. The reform question is not whether Nigerian TVE educators want EdTech they do but whether the institutional architecture exists to convert that willingness into sustained pedagogical practice. It does not, and this failure is a governance failure, not a teacher failure.

On the third research question concerning optimisation strategies, the analytical review identifies four non-negotiable preconditions: systemic curriculum reform, structured teacher capacity building, deliberate infrastructure investment, and accountability-driven public-private collaboration. Emerging technologies must be integrated into TVET programmes through structured institutional processes not ad hoc adoption with sufficient stakeholder involvement, targeted training, and policy backing to ensure sustainability (Industrial Technology Education Research Journal, 2023). Anything less risks producing the same outcome Nigeria has repeatedly experienced: well-intentioned reform initiatives that dissolve into isolated, unsustainable pilot projects.

For engineering and technical education, the implications are both immediate and long-term. The use of ICT and technological pedagogies towards competence and innovation-focused education is pivotal in a knowledge economy and mandatory for sustainable development (UN DESA, 2023). Nigerian engineering training cannot continue to be delivered through pedagogical models designed for a pre-digital industrial economy. Virtual simulation, computer-aided design instruction, and AI-assisted problem-solving environments must become standard features of engineering TVET not aspirational additions. The study contends that every year Nigeria delays this transition is a year of productive human capital irreversibly lost to the global economy.

This study's findings align consistently with the scholarly consensus. A robust educational framework that integrates sustainability practices and enhances local technological capabilities is essential for achieving Nigeria's national development goals, including the deployment of renewable energy technologies critical to its Energy Transition Plan (David & Daniels, 2024). Coherent policy frameworks aligning TVET with evolving labour markets and sustainability priorities are urgently needed to foster inclusive and transformative development outcomes (Zakiyudin & Hasim, 2025). This study's argument that EdTech is a structural prerequisite not a supplementary luxury for TVE reform is therefore not a novel claim but a well-evidenced position that Nigerian policy has persistently refused to operationalise.

This study provide a coherent conceptual architecture for future researcher by constructing a theoretically integrated framework anchoring EdTech integration on Constructivism, Systems Theory, TPACK, and Human Capital Theory. Also it challenges the celebratory EdTech discourse dominant in policy documents, insisting on contextual interrogation of *how* and *for whom* digital integration delivers outcomes in resource-constrained TVET environments. This study further establishes an explicit causal chain linking EdTech integration to sustainable national development a linkage undertheorised in the Nigerian TVE literature and articulates the conditions under which this chain holds.

Conclusion

The critical analytical review revealed a sector of constitutionally recognised importance but systemic neglect chronically underfunded, institutionally unprepared, pedagogically outdated, and digitally marginalised. The study demonstrated that virtual laboratories, simulation environments, blended learning, and AI-assisted instruction offer contextually viable pathways to transformation, but only within a reformed institutional architecture that provides the structural preconditions for their effective deployment.Government must take the lead in integrating EdTech into public institutions, supported by strategic partnerships with the private sector, development agencies, and non-governmental organisations backed by data-driven decision-making that prioritises real-time accountability and measurable outcomes. Sustainable national development in Nigeria cannot be achieved through a TVE system that remains technologically peripheral. Educational technology is not a future ambition it is a present necessity, and its systematic integration into TVE is the defining reform obligation of Nigeria's education governance in the twenty-first century.

Recommendations

1. The federal government must enact enforceable legislation establishing minimum EdTech standards for all TVE institutions, linked directly to NBTE accreditation and public funding eligibility.
2. Technical and Vocational Education institutions must restructure curriculum, pedagogy, and governance simultaneously, embedding EdTech as an institution-wide instructional mode across all technical disciplines rather than confining it to standalone ICT courses.
3. Open-source virtual laboratory platforms, mobile-compatible learning management systems, and locally adapted simulation software must be prioritised as cost-effective, contextually appropriate solutions.
4. Industry partners must assume co-ownership of curriculum design, provide industry-standard digital equipment, and commit to structured internship placements and measurable graduate employment targets formalised within legal partnership agreements.

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ARTIFICIAL INTELLIGENCE AS ASSESSMENT INFRASTRUCTURE FOR BRIDGING THEORY AND PRACTICE IN RESEARC-ASED SCIENCE EDUCATION: A POSITION PAPER

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Abstract

The persistent gap between research-based assessment theory and classroom practice remains a defining challenge in science education. Despite decades of evidence supporting formative assessment, constructivist learning, and psychometric rigor, implementation remains inconsistent and structurally constrained. This paper advances a bounded claim: the research–practice gap is infrastructural, and artificial intelligence represents the most viable infrastructure for operationalizing research-based assessment at scale under conditions of scale, variability, and resource constraint. Drawing on scholarship from leading researchers and evidence from top-tier journals, the paper demonstrates how AI enables adaptive assessment, real-time feedback, automated scoring, and scalable psychometric validation. An AI-Integrated Psychometric Assessment Framework (AIPAF) is proposed, conceptualizing AI as a mediating layer connecting theoretical foundations, validation processes, and classroom practice through continuous feedback. Critical concerns—bias, opacity, construct narrowing, and teacher de-skilling—are reframed as governance challenges requiring regulation rather than rejection. The paper evaluates non-AI alternatives, synthesizes empirical evidence, and addresses cost barriers, concluding that AI is a foundational systemic enabler necessary to align educational practice with established research. The framework is illustrated through alignment with Nigeria's revised curriculum, but AIPAF is a universal architecture effective in any education system facing challenges of scale and resource constraint.

Keywords: *Artificial Intelligence, Assessment Infrastructure, Formative Assessment, Psychometrics, Research-To-Practice Gap*

Introduction

The last century has seen science education research establish a robust evidence base on effective assessment practices. Black and Wiliam (1998, 2009) demonstrated that formative assessment significantly improves student learning, while subsequent research emphasized feedback, conceptual alignment, and inquiry-based evaluation (Heritage, 2010). Psychometric principles such as item difficulty, discrimination, reliability, and validity, provide technical infrastructure for designing defensible assessments (Ubi & Udemba, 2021). Despite this foundation, classroom practice remains dominated by summative, standardized approaches that fail to capture deeper scientific reasoning. Teachers rely on traditional formats that do not reflect students' learning processes. Researchers publish validated frameworks that rarely survive transition to classrooms (Coburn, 2003; Udemba & Adenji, 2025).

This misalignment is acute in Nigeria's revised Basic Education Curriculum (BEC) and Senior Secondary Education Curriculum (SSEC) (2025), which mandate inquiry-based learning, competency-based assessment, and reduced content for "sharper minds" (Federal Ministry of Education, 2025, p. 3). The curriculum requires 40% continuous assessment, yet infrastructure to

implement this at scale does not exist. The National Policy on Education acknowledges that "without corresponding changes in assessment infrastructure, the curriculum's aims cannot be achieved" (NERDC, 2025, p. 25). This disconnect reflects Coburn's (2003) failure of scale: research-informed innovations fail to translate into sustained practice. The problem is not weak research but missing infrastructure. This paper advances a bounded claim: the research–practice gap is structural, and AI represents the most viable infrastructure for addressing this gap under conditions of scale, variability, and resource constraint. The claim is conditional: where such capabilities are required at scale and governance mechanisms can be established, AI becomes functionally necessary.

Defining Infrastructure and Its Bounds

Star and Ruhleder (1996) define infrastructure as foundational systems enabling routine operations at scale, characterized by standardization, reliability, capacity for volume, invisibility in use, and integration into practice. AI is becoming infrastructure for assessment, not as a special add-on but as a basic layer making research-based practice feasible under real-world constraints. The central claim is restricted to specific boundary conditions. Scale refers to systems where student-to-teacher ratios exceed 30:1. Variability refers to contexts where student differences render uniform assessment invalid. Resource constraint refers to settings where teacher time for assessment falls below two hours per student per week. Outside these bounds, the necessity claim may not hold. While grounded in Nigeria's policy context, the infrastructural logic, and the AI-Integrated Psychometric Assessment Framework (AIPAF) proposed later, is universal. Nigeria serves as a compelling use case, not a boundary condition.

Original Contributions to This Position Paper

This paper advances several original contributions. First, it offers an infrastructural explanation of the theory-practice gap, shifting the solution space from professional development and curriculum reform to systemic infrastructure redesign. Second, it proposes the AI-Integrated Psychometric Assessment Framework (AIPAF), a novel framework systematically integrating AI capabilities, theoretical principles, and psychometric governance into coherent assessment architecture. Third, it provides psychometric governance architecture for AI-enabled assessment, embedding explicit mechanisms for validity, reliability, fairness, and transparency, which addresses a critical gap in the literature. Fourth, it defines boundary conditions under which AI becomes functionally necessary: scale, variability, and resource constraint. Fifth, it presents a universal infrastructure model applicable beyond Nigeria, with Nigeria serving as a compelling use case rather than a boundary condition. Sixth, it offers a conceptual reframing of AI from educational tool to educational infrastructure, with profound implications for how AI is designed, deployed, and governed.

This paper proceeds as follows. Section 2 establishes that the research-practice gap is structural. Section 3 provides theoretical grounding. Section 4 demonstrates AI's infrastructural capabilities. Section 5 presents AIPAF. Sections 6–8 elaborate feedback architecture, governance, and cost considerations. Sections 9–10 address implications, limitations, and future directions. Section 11 concludes.

The Structural Nature of the Research–Practice Gap

The research–practice gap is not theoretical inadequacy but implementation failure. Coburn (2003) argues that educational reform fails due to systemic constraints, not teacher resistance. Spillane, Reiser, and Reimer (2002) showed that policy implementation is mediated by cognitive frames shaped by structural conditions. Research-based assessment requires continuous formative feedback, adaptive calibration, and timely data interpretation, demands exceeding conventional classroom capacity, particularly in contexts with large class sizes and limited resources. Bennett (2015) identified this as the "design paradox": frameworks designed for optimal conditions must function under real-world constraints. Research-based assessment frameworks have been designed without attention to infrastructural conditions for implementation (Penuel & Shepard, 2016).

What Research-Based Assessment Requires

Research-based assessment requires continuous individualized feedback, adaptive instructional adjustment, psychometrically sound measurement, and ongoing data interpretation. These impose cognitive, temporal, and technical demands exceeding traditional systems. A teacher managing large classes cannot generate calibrated items, score open-ended responses consistently, provide real-time feedback, or analyze performance patterns. These are structural constraints, not failures of knowledge or effort.

Mismatch between System Capacity and Assessment Demands

Research-based frameworks presuppose responsiveness, individualization, and analytic processing exceeding the bounded capacity of human-centered systems. Teachers operate under simultaneity, attending to dozens of learners generating distinct evidence streams. Even highly skilled teachers cannot sustain iterative cycles of evidence interpretation that formative theory prescribes. Non-technological responses, training, reform, mandates, cannot remove this constraint; they intensify it (Fullan, 2007). Reforms follow a pattern of adoption, partial implementation, and reversion to prior practices (Tyack & Cuban, 1995). This pattern occurred in Nigeria's 2012 UBE curriculum, which failed because assessment infrastructure did not support continuous evaluation (Udemba & Adenji, 2025). The 2025 curriculum faces the same risk without infrastructural change.

Infrastructure as the Missing Layer

When implementation fails, failure is attributed to teacher resistance or cultural barriers. These factors exist, but they are symptoms of a deeper problem; which are the absence of infrastructure capable of operationalizing research principles under real-world constraints. Capacity problems of this scale require infrastructural solutions, not just professional development workshops.

Why Artificial Intelligence Rather Than Alternative Assessment Infrastructures?

A necessary step in justifying AI as infrastructure is to examine whether alternative approaches could plausibly resolve the structural gap. Three dominant non-AI strategies namely professional development, policy reform, and curriculum redesign have been pursued over the past three decades. However, the argument that AI represents the most viable infrastructure requires systematic comparison with alternatives evaluated against criteria derived from research-based

assessment demands. Teacher-only systems achieve flexibility and contextual sensitivity but fail catastrophically on scalability and consistency. Research-based assessment demands individualized feedback and continuous interpretation exceeding what teacher-only systems sustain (Penuel & Shepard, 2016). The "grammar of schooling" (Tyack & Cuban, 1995) ensures reversion to administratively efficient but pedagogically limited practices. Professional development (PD) models enhance teacher capacity but do not reduce cognitive and temporal demands of implementing formative assessment. Yoon et al. (2007) demonstrated that the effects are variable and unsustainable, particularly in systems characterized by large class sizes and limited time for assessment design and feedback.

Policy reform approaches mandate formative assessment but do not provide operational mechanisms. As Fullan (2007) noted that mandates often produce compliance-oriented practices that approximate rather than realize research-based assessment. Curriculum redesign introduces better-aligned tasks but without corresponding assessment infrastructure, these tasks are evaluated using traditional scoring (Penuel & Shepard, 2016). Curriculum redesign addresses what is assessed but not how assessment is operationalized. All operate within existing capacity constraints; none fundamentally alters the system's ability to process learner data, generate calibrated tasks, or provide individualized feedback at scale.

Learning management systems provide platforms for delivery and basic data aggregation but lack intelligence to provide individualized feedback, adapt to student performance, or support psychometric calibration. They transfer rather than reduce teacher workload. Learning analytics systems identify patterns and surface insights (Siemens & Baker, 2012) but not the full cycle of evidence identification, feedback generation, and adaptive adjustment. They assist teacher judgment but do not operationalize research-based assessment at scale. Educational data warehouses aggregate large-scale data for reporting and predictive modeling but are not designed for real-time classroom feedback or individual-level adaptation.

Computer-adaptive testing systems adjust item difficulty based on performance (Weiss & Kingsbury, 1984; van der Linden & Glas, 2010) but are typically limited to selected-response items and do not support open-ended inquiry tasks or process-oriented assessment. Hybrid human-AI systems combine teacher judgment with algorithmic support (Molenaar, 2022) but may lack integration required for continuous, theory-aligned assessment across multiple activities. AI-enabled assessment infrastructure integrates adaptive assessment, real-time feedback, automated scoring, learning analytics, and psychometric validation into a unified system. It addresses capacity constraints rendering other infrastructures insufficient.

Comparative analysis reveals a clear pattern. Teacher-only, PD, policy, and curriculum approaches operate within existing capacity constraints. LMS, analytics, and data warehouses provide partial infrastructure. Computer-adaptive testing addresses measurement precision but is limited in task types. Hybrid systems improve efficiency but may lack integration. AI-enabled infrastructure is the only approach simultaneously addressing scalability, adaptability, feedback capacity, assessment precision, psychometric support, implementation feasibility, and sustainability. This is not a claim of inevitability. AI infrastructure requires substantial upfront investment, ongoing governance, and careful validation. The argument is conditional: where scale, variability, and resource constraint require computational infrastructure, AI is currently the most developed infrastructure.

Theoretical Alignment
The structural nature of the gap has been established; therefore it is imperative to provide the theoretical grounding for the paper's argument, aligning AI with constructivist theory, formative assessment theory, and evidence-centered design. It also acknowledges irreducible tensions where they exist.

Constructivism
The theoretical foundation is grounded in the work of Piaget (1970) and Vygotsky (1978), constructivism emphasizes active knowledge construction and formative processes. Assessment is ongoing, embedded in learning. AI supports constructivist assessment through adaptive scaffolding, continuous monitoring, and items probing higher-order thinking. Baker (2016) showed AI detects engagement and affect; Luckin (2018) demonstrated adaptive scaffolding aligned with Vygotskian principles. Litman (2016) and Dzikovska et al. (2016) showed NLP evaluates open-ended science responses.

Formative Assessment Theory
Formative assessment requires continuous feedback loops that inform both teaching and learning (Black & Wiliam, 2009). Traditional practices are constrained by large classes and limited time. AI enables real-time feedback, overcoming capacity constraints.

Feedback theory
Feedback theory (Hattie & Timperley, 2007; Shute, 2008) explains how timely, specific, and actionable information improves learning by reducing the gap between current and desired performance. Evidence consistently identifies feedback as one of the strongest influences on student achievement, particularly when delivered immediately and tailored to learner needs. Within AIPAF, this theory provides the rationale for AI-enabled feedback systems that deliver scalable, real-time, and individualized support for learning and instructional improvement.

Evidence-Centered Design
The evidence-centered design (ECD) (Mislevy et al., 2003) emphasizes alignment between assessment tasks, the evidence they generate, and the interpretations made from that evidence. AI enhances ECD through automated item generation, real-time evidence identification, and adaptive task selection.

Distributed Cognition and Human-AI Co-Regulation
Distributed cognition theory (Hutchins, 1995) holds that cognitive processes distribute across people, tools, and environments. AI is not a replacement for teacher cognition but a cognitive partner extending system processing capacity. Human-AI co-regulation theory (Molenaar, 2022) proposes effective learning occurs when cognitive and regulatory processes distribute across learners, teachers, and technological agents. AIPAF operationalizes co-regulation through dual feedback architecture: the pedagogical loop keeps human judgment central, while the AI loop handles routine classification.

Sociotechnical Systems Theory
Sociotechnical systems theory emphasizes interdependence of social and technical elements (Trist & Bamforth, 1951). Assessment infrastructure is sociotechnical: a configuration of people,

practices, and technology. AIPAF recognizes this by embedding teacher mediation, governance, and professional development alongside AI capabilities.

Theoretical Tensions

Constructivism and ECD emerge from distinct commitments not fully reconcilable. Constructivism treats knowledge as situated; ECD assumes stable latent constructs. AI formalization risks privileging computationally tractable constructs (Selwyn, 2022). One pragmatic resolution treats constructivism as learning theory and ECD as measurement methodology, compatible at operational level (Mislevy, 2018). AIPAF addresses this through dual feedback architecture.

Theoretical Alignment Synthesis

The AI-Integrated Psychometric Assessment Framework (AIPAF) integrates constructivism, formative assessment theory, feedback theory, evidence-centered design, distributed cognition, human–AI co-regulation, and sociotechnical systems theory into unified assessment architecture. Together, these perspectives position assessment as a continuous, evidence-based process in which AI augments human judgment through automated evidence generation, analysis, and feedback while maintaining psychometric rigor and pedagogical relevance. The framework reconciles learning, measurement, and governance perspectives by combining learner-centered assessment with valid inference, human oversight, and ethical accountability. Within AIPAF, AI functions as a cognitive and instructional partner that enhances feedback, assessment quality, and decision-making without replacing teacher judgment, thereby supporting adaptive, transparent, and trustworthy assessment practices. The argument now demonstrates AI's infrastructural capabilities and empirical evidence.

Artificial Intelligence as Assessment Infrastructure

If the failure in research-practice gap is structural, then the solution must be infrastructural. Thus, artificial intelligence (AI) addresses structural capacity limitations by providing the computational layer for research-based assessment at scale. However, not all AI is equivalent. The term "AI" encompasses multiple computational techniques with different implications for assessment.

Disaggregating Artificial Intelligence

Among the various AI computational techniques, supervised learning systems are trained on human-scored responses, which are most relevant for automated scoring and carry risks of bias amplification when training data reflects existing inequities (Baker & Hawn, 2022). Generative AI enables item generation but introduces hallucination risks (Ji et al., 2023; Kasneci et al., 2023), while explainable AI (XAI) renders decisions interpretable (Samek et al., 2019). The framework assumes validated and explainable AI systems.

Explainable AI as Governance Requirement

AI operations must be interpretable. Black-box AI is incompatible with defensible assessment (Selwyn, 2022; Akgun & Greenhow, 2022). The explainable AI (XAI) serves four functions: (1) teacher trust: teachers act on analytics when they understand why (Holstein et al., 2019; Viberg et al., 2024); (2) validation and bias detection: XAI enables audit (Hariharasitaraman et al., 2025); (3) student metacognition: age-appropriate explanations support learning (Holstein et al., 2019;

Feldman-Maggor et al., 2024); (4) curriculum alignment: opacity contradicts emphasis on transparency.

Generative AI as Boundary Condition

GenAI offers capabilities: collaborative assessment design (Human-AI collaboration, 2025), formative feedback (Prompting better feedback, 2025), and Nigerian learning gains (World Bank, 2025). GenAI has hallucination and reliability concerns (Ji et al., 2023), validation challenges (GPT-4o bias, 2025), and explainability limitations. However, AIPAF includes GenAI due to its psychometric validation capabilities to implement psychometric governance. Also, the teachers equally perform moderation and quality assurance of the output the GenAI using human verification, curated knowledge bases, continuous monitoring, and transparency. AIPAF assumes curated feedback banks, explainable, validated, developmentally controlled.

Features of AI Capabilities

Generally, the AI capabilities include the following features:

1. Adaptive Assessment: AI adjusts task difficulty dynamically, supporting personalized learning (Luckin, 2018). Computer-adaptive testing reduces test length by 50% while maintaining precision (Weiss & Kingsbury, 1984; van der Linden & Glas, 2010).
2. Real-Time Feedback: AI enables immediate feedback. Meta-analyses report effect sizes of 0.66 for intelligent tutoring systems (Kulik & Fletcher, 2016; Steenbergen-Hu & Cooper, 2013; Ma et al., 2014).
3. Automated Scoring: NLP evaluates open-ended responses consistently. Human-AI agreement ranges from .81 to .94 (Shermis, 2014; Williamson, Xi, & Breyer, 2012).
4. Learning Analytics: AI identifies patterns in learning data, supporting instructional decision-making (Siemens & Baker, 2012; Long & Siemens, 2011).
5. AI-Generated Assessment Items: AI can generate items with acceptable psychometric properties (Udemba, Odiong, & Akomolafe, 2025), requiring careful validation (Von Davier, 2019).
6. AI-Assisted Proctoring: AI proctoring maintains integrity in online environments (Udemba & Zumbo, 2025).

Empirical Evidence on AI Effectiveness

Systematic reviews indicate AI-supported assessment improves engagement, feedback quality, and outcomes (Zawacki-Richter et al., 2019). Meta-analyses confirm effect sizes of 0.66 for intelligent tutoring (Kulik & Fletcher, 2016). Immediate feedback produces effect sizes double delayed feedback (Hattie & Timperley, 2007). AI enables qualitative scalability, transforming assessment from periodic activity to continuous process (Luckin, 2018; Baker, 2016). In summary, the evidence reveals that AI-enabled assessment systems improve feedback timeliness, enhance scoring efficiency, and support data-driven instructional decisions. More importantly, they extend the operational capacity of assessment systems beyond what is feasible through human effort alone. It is this expansion of capacity, rather than isolated gains in effectiveness that provides the strongest empirical support for positioning AI as emerging infrastructure in research-based assessment. The argument now presents a novel framework that operationalizes the integration of theory, AI, and governance.

Conceptual Framework: AI-Integrated Psychometric Assessment Framework (AIPAF)

The design of effective assessment systems is fundamentally rooted in learning theory. Therefore, based on the theoretical foundation underpinning this study, the present study proposes a framework titled: AI-Integrated Psychometric Assessment Framework (AIPAF). The framework conceptualizes the integration of theoretical, empirical, and methodological perspectives across educational psychology, artificial intelligence capabilities, and psychometrics. As illustrated in Figure 1. The proposed framework a closed-loop, AI-driven assessment ecosystem integrating four core components: Theoretical Foundation, AI Capabilities, Psychometric Validation, and a Pipeline System comprising AI Tools, Assessment Practice, Learning Outcomes, and Pedagogical Feedback. The Theoretical Foundation is grounded in constructivist learning theory (Jean Piaget; Lev Vygotsky), formative assessment principles, and evidence-centered design (Robert Mislevy), provides the epistemic basis guiding all system components.

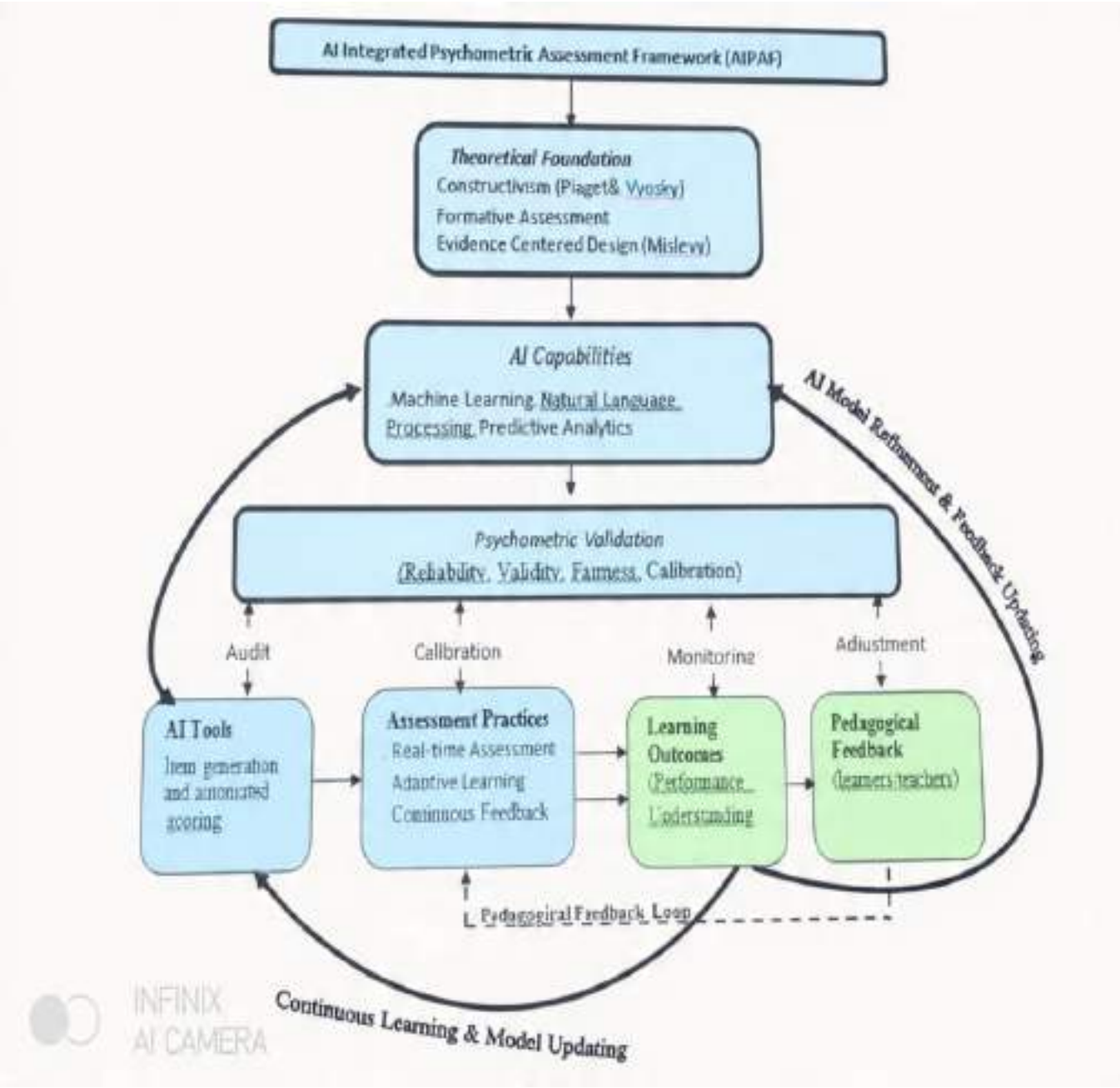

Figure 1: AI-Integrated Psychometric Assessment Framework (AIPAF)

The framework comprises four horizontal layers with bidirectional feedback flows.

Layer 1: Theoretical Foundations includes constructivism, formative assessment theory, feedback theory, evidence-centered design, distributed cognition, human-AI co-regulation, and sociotechnical systems theory. Layer 2: AI Capabilities includes process traceability, explainable AI (LIME, SHAP, G-SHAP), curated feedback selection, learning analytics, and automated classification. Layer 3: Psychometric Validation governs validity, reliability, fairness, and

transparency. Layer 4: Assessment Pipeline comprises AI Tools, Assessment Practice, Learning Outcomes, and Pedagogical Feedback. Bidirectional arrows indicate two feedback loops: Pedagogical Loop (human-centered) and AI System Loop (machine-driven optimization).

The AIPAF Components

AIPAF is structured around four interdependent components. The Theoretical Foundation provides epistemological and pedagogical grounding of the framework. The AI Capabilities Layer functions as a mediating layer, translating theoretical principles into executable processes. The Psychometric Validation Layer governs all stages through audit, calibration, monitoring, and adjustment. The Pipeline System comprises AI Tools, Assessment Practice, Learning Outcomes, and Pedagogical Feedback.

Theoretical Foundation Layer

The Theoretical Foundation provides the epistemological and pedagogical grounding of the framework. It integrates constructivist learning theory (Jean Piaget; Lev Vygotsky), formative assessment principles, and evidence-centered design (Robert Mislevy). Collectively, these perspectives define how knowledge is constructed, how learning should be assessed, and how evidence should be generated and interpreted. In the framework, this component functions as a constraint and alignment mechanism, ensuring that all AI-driven processes, assessment designs, and interpretations of learning outcomes remain pedagogically meaningful and theoretically coherent. It permeates all other components rather than operating as a linear starting point.

AI Capabilities Layer

AI Capabilities constitute the computational engine of the framework, encompassing machine learning, natural language processing, and predictive analytics. These technologies enable automated item generation, intelligent scoring, pattern detection, and predictive modeling of learner performance. This component is dynamically linked to Learning Outcomes through the AI Model Refinement and Updating Loop, whereby empirical performance data continuously inform model retraining and optimization. Consequently, AI Capabilities evolve iteratively, improving their accuracy, adaptively, and contextual relevance over time.

Psychometric Validation Layer

Psychometric Validation ensures the scientific integrity of the assessment system by enforcing standards of reliability, validity, fairness, and calibration. Unlike traditional linear validation models, this component operates concurrently with AI Tools, forming an embedded quality assurance mechanism. It continuously evaluates both generated assessment items and automated scoring outputs, ensuring that all measures remain consistent, unbiased, and aligned with intended constructs. Additionally, it supports calibration processes that maintain measurement precision across diverse learner populations and contexts.

Pipeline System Layer

The Pipeline System represents the operational core of the framework and consists of four sequential yet interdependent stages: AI Tools, Assessment Practice, Learning Outcomes, and Pedagogical Feedback.

AI Tools
AI Tools operationalize AI Capabilities into functional assessment instruments, specifically through item generation and automated scoring. These tools produce structured assessment inputs that are deployed within educational settings.

Assessment Practice
Assessment Practice serves as the central execution environment, where AI-generated assessments are implemented in classroom contexts. At this stage, Real-Time Assessment occurs, capturing learner responses instantaneously. The immediacy of this process enables the system to generate two critical outputs: Adaptive Instructions that involve dynamically adjusts based on learner performance. Task difficulty, sequencing, and scaffolding are modified ((VanLehn, 2011; Holmes et al., 2019). Thirdly, is Continuous Feedback by providing ongoing, specific, actionable feedback to both learners and educators. It drives self-regulated learning and performance improvement. So, it is consistent with feedback theory (Hattie & Timperley, 2007; Nicol & Macfarlane-Dick, 2006). These outputs flow directly into the Learning Outcomes stage.

Learning Outcomes
Learning Outcomes represent the measurable outputs of the system, encompassing learner performance and depth of understanding. This stage functions as the primary feedback hub, linking instructional processes with system-level intelligence. Importantly, Learning Outcomes drive two fundamental feedback mechanisms. The first one is AI Model Refinement and Updating Loop that connects to AI Capabilities, enabling continuous improvement of underlying models. The second is Continuous Learning and Model Updating Loop that connects to AI Tools, ensuring that assessment instruments evolve in alignment with observed learner data.

Pedagogical Feedback
Pedagogical Feedback captures interpretive insights from both learners and teachers, contextualizing quantitative outcomes within real instructional environments. It forms a Pedagogical Feedback Loop, reinforcing the relationship between assessment results and instructional decision-making. This component ensures that human judgment and experiential knowledge remain integral to the system, preventing over-reliance on automated processes.

Feedback Systems: Dual-Loop Human-AI Governance Architecture
The Pedagogical Feedback Loop connects pedagogical feedback stage (teachers) to assessment practice. At this point teachers review AI-generated analytics, approve or edit AI-selected feedback, and adjust instruction and support learners. The AI System Feedback Loop connects learning outcomes to AI capabilities and tools, enabling continuous model refinement and iterative adaptation.
AI refines classifications, feedback selections, and analytics based on accumulating data. Integration ensures human judgment remains central while machine learning drives improvement. Teachers can override AI suggestions, flag disagreements, and contribute to system refinement.
Those two feedback mechanisms formed the Dual-Loop Architecture that ensures human-centered pedagogy through pedagogical loop and machine-driven optimization through AI system loop, positioning AI as augmenting teacher expertise (Luckin, 2018).

System Control and Optimization

The framework incorporates embedded control processes: audit, monitoring, calibration, and adjustment, primarily associated with AI Capabilities and Psychometric Validation. These processes ensure ongoing system integrity, detect potential biases or model drift, and maintain alignment with psychometric and pedagogical standards.

Integrated System Dynamics

The AIPAAF operates through two tightly coupled flows: Forward operational flow begins with Theoretical Foundation, informing AI Capabilities Layer, driving AI Tools enabling Assessment Practice (Real-Time Assessment). Students receive Adaptive Instruction and Continuous Feedback, generating Learning Outcomes that inform Pedagogical Feedback. Backward adaptive flow connects Learning Outcomes to AI Capabilities and Tools. These bidirectional flows establish a self-improving ecosystem, in which instructional practices, assessment mechanisms, and AI models co-evolve continuously.

Positioning AIPAF Relative to Existing Frameworks

AIPAF builds on established frameworks while addressing limitations. ECD (Mislevy et al., 2003) predates AI; AIPAF specifies AI's role in evidence identification and real-time adaptation. Assessment Triangle (Pellegrino, Chudowsky, & Glaser, 2001) lacks computational infrastructure; AIPAF adds AI mediating layer. Luckin's framework (2016) lacks governance; AIPAF adds Psychometric Validation Layer. Baker's framework (2016) is ITS-specific; AIPAF generalizes. FAIR framework (Akgun & Greenhow, 2022) provides governance but not operational design; AIPAF integrates principles. Noble's framework (2018) addresses bias; AIPAF incorporates pre-deployment testing and monitoring.

Summary

The AIPAAF represents a fully integrated, adaptive assessment system in which: pedagogical theory ensures conceptual validity, artificial intelligence enables scalability and responsiveness, psychometric validation guarantees measurement integrity, and continuous feedback loops drive ongoing system evolution. This architecture positions assessment not as a static measurement activity, but as a dynamic, intelligent, and pedagogically grounded process of continuous learning optimization.

The New Revised Nigeria Curriculum

The new Nigeria Basic Education Curriculum (2025) is fundamentally based on inquiry based learning and advocates for light loads and sharper minds (Federal Ministry of Education, 2025). This curriculum shift recognizes that traditional rote learning and summative assessment cannot produce the critical thinking, problem solving, and creativity skills required for 21st century development.

AIPAF as the Main AI Framework: Nigeria as Exemplar

Nigeria's revised curriculum mandates inquiry-based learning, reduced content, competency-based assessment, and 40% continuous assessment (NERDC, 2025; Federal Ministry of Education, 2025). These conditions exist worldwide. AIPAF is universal architecture; Nigeria is inaugural use case. Inquiry-based learning alignment: NLP evaluates open-ended inquiry responses and learning

analytics track conceptual change (Litman, 2016). Light loads enablement: automating routine tasks frees teachers. AI adaptive testing reduces test length by 50% (Weiss & Kingsbury, 1984). Continuous assessment fulfillment: dual feedback loops ensure meaningful assessment. Scalability: designed for large classes and limited infrastructure. Psychometric rigor: Validation Layer ensures validity, reliability, fairness, transparency.

Why Nigeria Represents a Critical Test Case

Nigeria constitutes valuable context due to intersecting factors: Scale, Nigeria has over 20 million students, WAEC and JAMB assessments are sat by hundreds of thousands annually; Resource constraints, large class sizes exceeding 50 students, limited infrastructure, insufficient training (Udemba & Adenji, 2025); Curriculum reform pressure, 2025 requirements cannot be implemented without infrastructural change (NERDC, 2025; Federal Ministry of Education, 2025); Regional inequities, AI infrastructure could reduce rather than reinforce disparities if governed equitably; Digital infrastructure, mobile penetration exceeds 100 million, internet approaches 50%, National Broadband Plan targets 70% by 2025; International relevance, conditions present in many education systems worldwide. Nigeria is not exceptional but exemplary; evidence contributes to global evidence base.

Operationalization of Curriculum Constructs into Observable Actions

The curriculum constructs are translated to observable behaviours as the learners engage in the following activities. The scientific process skills are operationalized when a student records observations systematically. Problem identification- when a student formulates an investigable question. Hypothesis formulation- through the “if...then...” structures. Experiment design through variable identification and control. Data collection is through tables and graphs creation. The data interpretation is through trends identification and evidence-based conclusion and the communication of results through report structure and scientific language. Safety through safety mentions. Collaboration is done through peer feedback and application through solution proposals.

Psychometric Governance

The framework's dual feedback loops require governance to maintain psychometric integrity. This section specifies how the Psychometric Validation Layer functions as a regulatory mechanism.

Core Measurement Principles

The governance layer operationalizes four core principles. Validity requires construct validity evidence for AI scored and AI generated assessments, including attention to consequential validity (Akgun & Greenhow, 2022). Reliability monitors inter rater agreement between AI predictions and expert human judgment (Kizilcec & Lee, 2022). Fairness requires pre deployment bias testing and ongoing monitoring for disparate impact (Noble, 2018). Transparency mandates that AI scoring systems provide interpretable outputs (Selwyn, 2022). Documented failures underscore the necessity of these governance mechanisms. Commercial proctoring systems have been documented to flag students with darker skin tones or non-standard accents at higher rates than white students speaking standard dialects (Swauger, 2020; Reese, 2021; Slaughter, 2021). Automated scoring systems have been shown to penalize creative or non-standard responses that deviate from training data patterns (Madaus, 1991; Cope et al., 2021).

Validity Argumentation within AIPAF

AIPAF generates, supports, monitors, and continuously refines validity evidence across multiple sources. Construct validity is supported through Behavioral Indicator Matrix mapping curriculum constructs to observable actions. Content validity through alignment with curriculum frameworks. Response- process validity through process traceability capturing student actions. Internal structure validity through psychometric analysis of classification patterns. Criterion-related validity through correlation with external measures. Consequential validity through evidence of beneficial outcomes without harmful unintended consequences. Validity is ongoing process, not one-time exercise.

Reliability and Generalizability

AI contributes to reliability through consistent scoring, inter-rater reliability, and decision consistency. Automated scoring achieves high human-AI agreement (Shermis, 2014). AIPAF acknowledges threats: algorithmic drift, model updates, contextual variability, changing data distributions.

Fairness Frameworks

Fairness embedded as foundational design principle. Algorithmic bias addressed through pre-deployment testing and ongoing monitoring. Differential prediction through validation studies. Differential item functioning through statistical analysis with maximum DIF threshold 0.05. Representation bias through diverse training data. Linguistic bias through multilingual training and code-switching tolerance. Cultural bias through participatory design. Equity implications through 80% rule ensuring classification accuracy for any subgroup not less than 80% of highest-performing.

Pre-Registered Validation Protocol

Validation studies powered to detect effect size 0.20, requiring $N \geq 200$ per subgroup (Baker & Hawn, 2022). AI classifications require Cohen's $\kappa \geq 0.80$ ($\kappa \geq 0.85$ for open-ended) (Shermis, 2014). Fairness metrics: DIF threshold 0.05; 80% rule (Akgun & Greenhow, 2022). Teacher-AI agreement below 0.75 triggers review. Three phases: calibration ($N \geq 300$), feasibility pilot ($N \geq 500$), efficacy trial ($N \geq 1,000$).

Human-AI Collaboration Models

Co-regulation model (Molenaar, 2022): AI handles routine tasks; teachers exercise judgment over non-routine decisions, aligning with distributed cognition (Hutchins, 1995). Human oversight embedded throughout: teachers review analytics, approve or edit feedback, exercise discretion; psychometricians and curriculum experts validate classifications; policymakers establish governance frameworks.

Addressing the Cost Barrier

AI requires substantial upfront investment across four layers: access infrastructure, computational infrastructure, system development, and governance (Holmes, Bialik, & Fadel, 2019). Solutions include open-source AI, public investment, philanthropic funding, tiered deployment, and regional shared infrastructure. Cost analysis of ASSISTments found per-student costs decrease at scale

(Feng et al., 2025). World Bank research in Nigeria found AI interventions among most cost-effective programs (World Bank, 2025). Teacher observation does not scale; AI has high upfront but low marginal costs.

Implications for Policy, Practice, and Research

Policy Implications

Governments require systemic investment: integration into national assessment systems with regulatory oversight; reliable infrastructure; regulatory frameworks mandating transparency, fairness, and teacher involvement; funding for validation research; tiered deployment. While framed for Nigeria, adaptable to any education system.

Practice Implications: Teacher Professional Development

Teacher capacity to mediate AI outputs is critical. Professional development should include foundational understanding, dashboard literacy, mediation and co-regulation, and ethical considerations (Molenaar, 2022). Ongoing support includes communities of practice, technical support, and lead teacher models. Teachers with higher AI understanding report more trust (Viberg et al., 2024).

Research Implications

Expand evidence base through cross-context validation studies, transparency in reporting, publication of AI failures (Akgun & Greenhow, 2022), longitudinal research, cost-effectiveness studies.

Psychometric Standards Implications

Update standards for AI-specific concerns: validation protocols, fairness auditing, transparency requirements, and co-regulation guidelines.

Limitations and Future Directions

Empirical Limitations

Evidence for AI in science assessment thinner than reading/mathematics (Zawacki-Richter et al., 2019). Most studies focus on essay scoring, not full range of science tasks. Transfer cannot be assumed. Nigerian studies focus on Economics and proctoring. Long-term impacts unknown.

Economic and Infrastructure Limitations

Cost-effectiveness not systematically evaluated. Cost barrier most acute where needed most. Infrastructure assumptions do not hold in resource-constrained settings.

Theoretical and Governance Limitations

Constructivism-ECD tension acknowledged but not resolved. Governance mechanisms require empirical validation.

Context-Specific Limitations and Mitigation Strategies

Infrastructure constraints require offline-first design and solar solutions. Teacher digital literacy requires differentiated professional development and simplified interfaces. Cost constraints require open-source development and public-private partnerships. Policy gaps require engagement with curriculum authorities. Linguistic diversity requires multilingual training data, code-switching tolerance, and teacher mediation.

Future Research Directions

Priority: validation studies; fairness and bias audits; efficacy studies; teacher mediation studies; cost-effectiveness analyses; design research for low-infrastructure environments; cross-context generalisability; epistemological impacts; GenAI integration as methods mature.

Cross-Context Generalisability

AIPAF is universal architecture adaptable to any system facing scale, variability, and resource constraints. Core principles reflect foundational requirements (Star & Ruhleder, 1996; Mislevy et al., 2003). Nigeria is compelling use case, not boundary condition. Implementation requires contextual adaptation in curriculum alignment, linguistic adaptation, validation, cost structure, and teacher professional development.

The Strongest Case Against AI as Assessment Infrastructure

Surveillance and Datafication: Critics argue AI constitutes surveillance intruding upon student privacy (Selwyn, 2022; Swauger, 2020). Response: AIPAF addresses through privacy-by-design: local processing, data minimization, transparency, purpose limitation.

Algorithmic Inequality and Bias Amplification: Critics argue AI encodes social biases (Noble, 2018; Buolamwini & Gebru, 2018; Baker & Hawn, 2022). Response: AIPAF embeds fairness as foundational design principle: pre-deployment bias testing, ongoing fairness audits, DIF analysis, 80% rule, recalibration if bias detected.

Teacher Deskilling and Loss of Professional Autonomy: Critics argue AI deskills teachers (Selwyn, 2019, 2022). Response: AIPAF positions AI as augmenting judgment through co-regulation (Molenaar, 2022); teachers review analytics, edit feedback, override when pedagogical judgment requires.

Construct Narrowing and Epistemic Reduction: Critics argue AI privileges computationally tractable constructs (Selwyn, 2022; Cope et al., 2021). Response: Behavioral Indicator Matrix aligned with curriculum outcomes rather than computational convenience; dual-loop architecture keeps human judgment central.

Commercial Platform Dependence: Critics argue dependence on commercial platforms (Selwyn, 2022). Response: AIPAF addresses through open-source development and public ownership; governance mandates data ownership remains with schools and students.

Educational Dehumanization: Critics argue AI reduces education to algorithmic processes (Selwyn, 2019, 2022). Response: AIPAF supports human relationships by freeing teachers for relational work; success depends on preserving human relationships.

Ethical Governance Deficits: Critics argue governance inadequate (Akgun & Greenhow, 2022). Response: Governance embedded as integral component; Psychometric Validation Layer ensures validity, reliability, fairness, transparency; teacher-flagged disagreement triggers review; research agenda includes governance research.

Testable Propositions Emerging from AIPAF

AIPAF generates testable propositions supporting its status as a research programme. AIPAF increases formative feedback frequency. AIPAF improves curriculum-assessment alignment. AIPAF achieves higher inter-rater reliability than human-only systems. AIPAF reduces teacher assessment workload. AIPAF demonstrates stronger validity evidence than traditional systems. Teacher mediation moderates effectiveness. Explainability increases teacher trust. Continuous feedback mediates learning outcomes. Fairness monitoring reduces bias. Cost-effectiveness improves with scale. These propositions are empirically testable through validation studies, fairness audits, efficacy trials, and cost-effectiveness analyses.

Research Agenda for AI-Enabled Assessment Infrastructure (2026–2036)

A decade-long research agenda organized into thematic streams: Validation research establishing psychometric properties across contexts. Bias and fairness research detecting, monitoring, and mitigating algorithmic bias. Teacher mediation research understanding and optimizing teacher-AI collaboration. Human-AI collaboration research developing and testing co-regulation models. Cost-effectiveness research evaluating economic viability. Cross-national studies examining generalisability across educational systems. Governance research developing and testing governance mechanisms. Low-resource implementation research developing and testing AI infrastructure in low-resource environments. Generative AI integration research investigating incorporation as validation methods mature. Each stream advances the field, strengthens the evidence base, and improves the framework.

Conclusion

The research–practice gap is not due to inadequate theory but insufficient implementation capacity. AI provides the missing infrastructure. The argument is supported by conceptual reasoning and emerging empirical evidence. While the evidence base remains incomplete, consistent findings indicate AI enhances feedback timeliness, improves efficiency, and expands operational capacity. AI offers a way to redistribute cognitive labour, enabling forms of assessment otherwise aspirational, while introducing risks requiring governance. The position is conditional but firm: if the goal is sustained alignment between research-based assessment and classroom practice at scale, computational infrastructure is required. AI is the most developed candidate. Success depends on governance, validation, and integration. The question is not whether AI will influence assessment, but how and under whose terms. Disengagement delegates governance to actors outside educational research. Engaging critically creates conditions for identifying and mitigating risks.
AIPAF offers a framework for transforming assessment infrastructure, grounded in theory, designed for resource-constrained contexts, governed by psychometric rigor. AIPAF is not context-

specific; it is a universal framework with compelling use cases. AI will not replace research-based assessment principles. Without AI, those principles will remain unrealized under conditions of scale and constraint. The bridge has been designed for decades. It is time to build it, with governance, evidence, and teachers at the center.

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ASSESSING AL-AUGMENTED INSTRUCTIONAL SYSTEM DESIGN FOR SCALABLE LEARNING IN PRIMARY SCHOOLS IN PANKSHIN LOCAL GOVERNMENT AREA.

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ABSTRACT

This study investigates the use of AI-augmented instructional system design for scalable learning in primary schools in Pankshin Local Government Area. Pankshin is a rural area. It has many primary schools. These schools face serious problems. These include too few teachers, too many pupils in each class, and a lack of learning materials. The problem is that the current teaching methods cannot reach every child well. AI-augmented systems could help. They can deliver lessons to many children at once. They can also adapt to each child's learning level. This study used a descriptive survey research design. A sample of 200 primary school teachers and 30 education officials were selected using random sampling. Data was collected using a structured questionnaire. The data was analyzed using mean scores and chi-square tests. Findings showed that teachers agree that AI can help with lesson delivery. They also believe that AI can make learning more personal for each child. However, there are major challenges. These include lack of electricity, poor internet, and lack of training. The study concludes that AI-augmented instructional design has great potential for Pankshin. But the government must first solve basic infrastructure problems. The study recommends investment in electricity and internet. It also recommends training for teachers. The theoretical framework used is the Technology Acceptance Model (TAM). This model helps to understand why people accept or reject new technology.

Keywords: AI-Augmented Instruction, Instructional System Design, Scalable Learning, Primary Schools, Pankshin, Educational Technology

Introduction

Artificial intelligence is changing many parts of life. AI means machines that can think and learn like humans. In education, AI is now being used to help teachers. It can create lesson plans. It can grade homework. It can even teach students directly. AI-augmented instructional system design means using AI to plan and deliver lessons. This is different from old methods. In the old method, one teacher stands in front of many children. The teacher talks. The children listen. But this method has limits. A teacher cannot give personal attention to fifty children at once. Some children learn fast. Some learn slow. Some need more help. The old method leaves many children behind. AI can change this. AI can give each child a personal learning path. It can show a child more examples if they do not understand. It can skip ahead if they already know the topic. This is called scalable learning. Scalable learning means that the same system can teach one child or one million children. It works the same way. This is very important for places like Pankshin. There are many children but few teachers. AI can fill the gap (Holmes et al., 2019).

Primary school is the foundation of all education. What a child learns in primary school stays with them for life. They learn to read. They learn to write. They learn basic math. If a child misses these

skills, they will struggle forever. In Nigeria, primary school enrollment is high. Many children go to school. But the quality is low. According to the United Nations Children's Fund (UNICEF, 2020), over 70% of children in rural Nigeria cannot read a simple sentence by age ten. This is a crisis. These children are not really learning. The problem is not that the children are not smart. The problem is the system. There are not enough teachers. The teachers that exist are not well trained. Class sizes are huge. In some schools in Pankshin, one teacher handles over one hundred children. That is impossible. No human can teach one hundred children at different levels at the same time. Something must change. AI-augmented systems offer a way out. A tablet or a phone with AI software can act like a personal tutor. It can work with each child at their own speed. It never gets tired. It can repeat a lesson one hundred times if needed. This is the promise of AI in education (Luckin et al., 2016).

Pankshin Local Government Area is in Plateau State, Nigeria. It is a rural area. The main occupation of the people is farming. Many people are poor. The government schools in Pankshin lack basic things. Some schools have no chairs. Some have no blackboards. Many have no electricity. The internet is very poor. Most teachers have never used a computer for teaching. They use chalk and talk. That is all they know. But the world is changing fast. Children in cities now learn with computers. They have access to information. Children in Pankshin do not. This creates a big gap. The gap is not fair. Every child deserves a good education. The Nigerian government has promised to provide quality education for all. This is part of the Sustainable Development Goals. Goal four is quality education for everyone. But promises are not enough. There must be action. AI-augmented instructional design could be the action needed. It can bring world-class learning to rural areas. It does not need a building. It does not need many teachers. It just needs a device and some power. Solar power can work. This is why this study is important. It looks at whether AI can really work in Pankshin (World Bank, 2021).

The problem is that technology is not magic. Just putting computers in a school does not mean children will learn. The system must be designed well. The instruction must be good. The AI must be set up correctly. Also, the teachers must accept it. If teachers reject the AI, it will fail. If parents do not trust it, it will fail. If the government does not support it, it will fail. There are many questions. Will the AI lessons be in Hausa or English? Will the AI understand the local culture? Will the AI work without internet? These are practical questions. They need answers. This study aims to provide those answers. It will assess the readiness of Pankshin for AI-augmented learning. It will ask teachers what they think. It will ask education officials what they think. It will identify the barriers. It will suggest solutions. The goal is to find a way to make scalable learning work in rural Nigeria. This is not just about technology. It is about giving every child a fair chance in life (Selwyn, 2019).

Statement of the Problem

The primary schools in Pankshin Local Government Area are in a state of crisis. The quality of learning is very low. Most children finish primary school without mastering basic math or reading. The main reason is the lack of human resources. There are far too few teachers. Many of the teachers that exist are not qualified. They did not receive proper training. Also, the pupil-to-teacher ratio is extremely high. In some schools, the ratio is 150 to one. This means a single teacher is responsible for one hundred and fifty children. That teacher cannot give individual attention. The teacher cannot know which child is struggling and which child is excelling. The teacher simply delivers a general lesson. The children who understand move on. The children who do not

understand fall behind. They stay behind forever. This is a waste of human potential. This problem is made worse by a lack of learning materials. There are no textbooks. There are no libraries. There are no computers. The teaching method is purely oral. The teacher talks. The children listen. But listening is not enough for deep learning. Children need to practice. They need feedback. They need to try and fail and try again. The current system does not provide this. Therefore, a new approach is needed. AI-augmented instructional system design offers a possible solution. It can provide personal tutoring at a massive scale. One AI system can teach thousands of children at the same time. It can give each child personal feedback. This could solve the teacher shortage problem. But will it work in Pankshin? That is the question this study seeks to answer (Akinwumi & Adeyemi, 2022).

There is a second part to the problem. Even if the technology is available, the people may not use it. Technology acceptance is a major issue in rural Nigeria. Many teachers fear technology. They think it will replace their jobs. They resist change. Also, there are infrastructure problems. Most schools in Pankshin have no electricity. The national power grid does not reach many villages. Even when it does, the power is unstable. There are frequent blackouts. Also, there is no internet. The mobile network is weak. Data is expensive. An AI system that needs constant internet will fail. The system must work offline. It must be powered by solar energy. Furthermore, the content must be local. The AI must speak Hausa. It must use local examples. If the AI talks about snow, children in Pankshin will not understand. They have never seen snow. The AI must talk about farming, about markets, about things they know. These are design challenges. They have not been solved yet. This study will investigate these challenges. It will ask the community what they need. It will assess the current state of infrastructure. It will make practical recommendations. The problem is urgent. Every year that passes, another group of children finishes primary school without learning. They will grow up without skills. They will remain poor. This cycle must be broken. AI may be the tool to break it (Nwosu & Okonkwo, 2021).

Aim And Objectives of The Study

The aim of this study is to assess AI-augmented instructional system design for scalable learning in primary schools in Pankshin Local Government Area. The specific objectives of the study are to:

1. Examine the level of awareness of AI-augmented instructional systems among primary school teachers in Pankshin.
2. Assess the perceived usefulness of AI-augmented systems for improving learning outcomes in Pankshin.
3. Identify the infrastructure challenges that hinder the adoption of AI-augmented learning in Pankshin.
4. Determine the relationship between teacher training and the acceptance of AI-augmented instructional systems.

Research Questions

The following research questions guided the study:

1. What is the level of awareness of AI-augmented instructional systems among primary school teachers in Pankshin?

2. How useful do teachers perceive AI-augmented systems to be for improving learning outcomes in Pankshin?
3. What infrastructure challenges hinder the adoption of AI-augmented learning in Pankshin?
4. What is the relationship between teacher training and the acceptance of AI-augmented instructional systems?

Hypotheses

The following hypotheses were tested at a 0.05 level of significance:

H_{01}: There is no significant relationship between teacher training and the acceptance of AI-augmented instructional systems in Pankshin.

H_{02}: There is no significant relationship between infrastructure availability and the successful implementation of AI-augmented learning in Pankshin.

Literature Review

The Concept of AI-Augmented Instructional Design

AI-augmented instructional design means using artificial intelligence to help create and deliver lessons. It is not about replacing the teacher. It is about giving the teacher superpowers. The AI can handle repetitive tasks. For example, the AI can grade multiple-choice questions. It can track which students are doing well and which are not. It can suggest which topics to review. This frees the teacher to do what humans do best. Humans are good at encouragement, empathy, and inspiration. Machines are good at repetition, calculation, and memory. Together, they are a strong team. AI-augmented systems can also personalize learning. In a normal classroom, all children do the same thing at the same time. This is not ideal. Some children are bored because the lesson is too easy. Some children are lost because the lesson is too hard. AI can fix this. The AI can give each child a different set of questions. It can adjust the difficulty in real time. If a child answers five questions correctly, the AI makes the next question harder. If the child gets two wrong in a row, the AI makes the next question easier. This is called adaptive learning. It is very powerful. Research shows that adaptive learning can improve test scores by a large margin. It works for all kinds of students. Fast learners move ahead quickly. Slow learners get the extra practice they need. No one is left behind. This is why AI-augmented design is so important for places like Pankshin. The range of student ability is very wide. Some children have never seen a book at home. Others have parents who can read. The AI can meet each child where they are (VanLehn, 2019).

The design of the system is very important. A bad design will fail even with good AI. Instructional system design is a process. It starts with understanding the learners. Who are they? What do they already know? What is their culture? Next, the designer sets clear goals. What should the learner be able to do after the lesson? Then, the designer creates content. This could be videos, quizzes, games, or readings. Then, the designer chooses how to deliver the content. Will it be on a tablet? On a phone? On a computer? Finally, the designer tests the system. Does it work? Do the learners learn? This process is called ADDIE. It stands for analyse, Design, Develop, Implement, and Evaluate. AI can help with all these steps. For example, AI can analyse data from past students to find common mistakes. Then it can design lessons that specifically address those mistakes. AI can also evaluate student performance instantly. It does not have to wait for a test at the end of the term. The system knows right away if a student understands. This allows for immediate correction.

For primary schools in Pankshin, this is a game changer. A child can get feedback in seconds, not weeks. The child can try again immediately. This builds confidence. The child sees progress. They feel smart. This motivates them to keep learning. Without this feedback loop, many children give up. They think they are stupid. They are not stupid. They just need a system that works for them (Reiser & Dempsey, 2018).

Scalable Learning in Rural Primary Schools

Scalable learning means that the same educational method can work for a small group or a very large group. For example, a one-on-one tutor is not scalable. It requires one tutor per student. That is too expensive. A classroom lecture is more scalable. One teacher can teach fifty students. But fifty is still a limit. A television broadcast is very scalable. One broadcast can reach millions. The problem with television is that it is not interactive. The viewer cannot ask questions. AI-augmented systems are both scalable and interactive. A single AI system hosted on a server can serve thousands of students at the same time. Each student gets a personalized experience. The AI talks to each student individually. It remembers what each student has learned. It asks questions. It gives feedback. This is the holy grail of education. It combines the personal touch of a tutor with the reach of a broadcast. For rural areas, this is essential. Rural areas do not have enough qualified teachers. It is hard to attract teachers to villages. The pay is low. The conditions are hard. Most teachers want to live in cities. So villages are left with few teachers. Those teachers are often the least qualified. This is not fair to the children. AI can solve this problem. The AI does not need to live in the village. It lives on a server. It can be anywhere. The children access it through a device. That device could be a cheap tablet. It could even be a shared phone. The cost is low compared to hiring many teachers. Governments in developing countries are now exploring this option. India has started using AI tutors in rural schools. Kenya has done the same. Early results are positive. Children in AI-supported classes learn more than children in traditional classes. They also enjoy school more. The AI is patient. It never shouts. It never gives up on a child. This is what scalable learning can bring to Pankshin (Zhang et al., 2020).

But there are challenges to scalability in Pankshin. The first challenge is language. Most AI systems work in English. But many children in Pankshin speak Hausa as their first language. They learn English in school, but it is not their mother tongue. Research shows that children learn best in their mother tongue. An AI that speaks only English will leave many children behind. The system must be multilingual. It must support Hausa. It should also support local dialects. This is technically possible. Speech recognition and translation have improved greatly. But it requires investment. The second challenge is content. The content must be relevant to rural life. Many educational apps are made for city children. They use city examples. They talk about subways, elevators, and supermarkets. Children in Pankshin have never seen these things. They do not understand them. The AI must use local examples. It must talk about chickens, goats, maize, and yams. It must use stories that reflect the local culture. If the content is foreign, the children will not connect with it. They will lose interest. The third challenge is power and connectivity. As mentioned earlier, many schools have no electricity. The AI system must work offline. It must be able to run on solar power. This is not impossible. There are now low-power devices that can run AI models locally. They do not need an internet connection after the initial setup. These devices can be charged with a small solar panel. This makes them suitable for rural Africa. The government needs to invest in these solutions. Without solving these three challenges, scalable learning will not work (Okonkwo & Ade-Ibijola, 2021).

Barriers to Technology Adoption in Rural Education

There are many barriers to adopting new technology in rural schools. The first barrier is attitude. Many teachers are afraid of technology. They have never used a computer. They do not understand how AI works. They fear it will take their jobs. This fear is understandable but misplaced. AI is not a replacement for teachers. It is a tool. A teacher with AI is like a carpenter with power tools. The tools make the work easier and better. But the carpenter is still essential. The teacher is still essential. The AI cannot give a hug. It cannot notice that a child is sad. It cannot inspire a child to dream big. Only a human teacher can do these things. So teachers should see AI as a helper, not a rival. Changing this attitude requires training and communication. Teachers must see the AI work. They must try it themselves. They must see that it helps them do their job better. If they see that they still have control, they will accept it. This is called the Technology Acceptance Model (TAM). TAM says that people accept technology if they find it useful and easy to use. So the AI system must be very simple. The buttons must be big. The instructions must be clear. It must work even if the teacher makes mistakes. If it is too hard to use, teachers will reject it. They will go back to chalk and talk. So designers must focus on simplicity. A system that works for a child should also work for a teacher (Davis, 1989).

The second barrier is cost. AI systems require hardware. The hardware costs money. A tablet that costs fifty dollars is still too much for many families in Pankshin. The government must provide the devices. The government must also maintain them. Tablets break. Screens crack. Batteries die. Who will fix them? There must be a repair plan. Spare parts must be available. Technicians must be trained. This adds to the cost. Also, the software must be updated. AI models improve over time. The system needs regular updates. These updates require data. Data costs money. The government must budget for these ongoing costs. Many technology projects in Africa fail because they only budget for the initial purchase. They forget about maintenance. After one year, the devices are broken. The project dies. This must not happen in Pankshin. A sustainable plan is needed. The third barrier is electricity. Even with solar panels, there are challenges. Solar panels need sunlight. During the rainy season, there is less sunlight. The batteries must be large enough to store power for cloudy days. Good solar systems are not cheap. Cheap solar systems fail quickly. The government must invest in quality equipment. It must also train someone in each school to maintain the solar system. This person could be a teacher or a community member. Without reliable power, the AI system is just a paperweight. These barriers are real, but they are not insurmountable. Many countries have overcome them. Rwanda has used solar-powered tablets to teach English in rural villages. The project was successful. Nigeria can learn from Rwanda. The key is careful planning and community involvement. The people of Pankshin must be part of the design process. They know their challenges best (Tondeur et al., 2020).

Benefits of AI For Primary Education

The benefits of AI for primary education are many. First, AI provides personalization. No two children are the same. They have different backgrounds, different speeds, and different interests. AI can adapt to each child. It can give extra reading practice to one child while giving math puzzles to another. This is impossible in a normal classroom. The teacher cannot be everywhere at once. But the AI can. It works with each child individually. It builds a profile for each child. It knows their strengths and weaknesses. It uses this knowledge to plan the next lesson. This is like having a personal tutor for every child. Research shows that personal tutoring improves learning by a large amount. Children learn faster. They remember more. They enjoy learning more. This is especially

important for struggling learners. In a normal class, struggling learners feel ashamed. They do not want to answer questions. They hide. With AI, no one sees their mistakes. The AI gives private feedback. The child can make mistakes without embarrassment. This reduces anxiety. It allows the child to take risks. Taking risks is how people learn (Woolf, 2019).

Second, AI provides immediate feedback. In a normal school, a child does homework. The teacher collects it. The teacher marks it after school. The child gets the paper back the next day or even later. By that time, the child has forgotten the problem. The learning moment is lost. With AI, feedback is instant. The child answers a question. The AI tells them right away if it is correct. If it is wrong, the AI shows the correct answer. It can even explain why the answer is wrong. This instant feedback strengthens learning. It helps the child correct misunderstandings immediately. It also keeps the child engaged. The child is playing a game. The game gives points. The child wants to keep playing. This is called gamification. AI can make learning feel like a game. There are levels, points, badges, and rewards. Children love games. They will spend hours playing a game. If learning is a game, they will spend hours learning. This is a powerful way to motivate children. For children in Pankshin, who may not have toys or video games at home, an AI learning game could be a source of joy. They will look forward to school. They will want to use the tablet. This solves the problem of attendance. When children enjoy school, they come to school (Gee, 2018).

Third, AI can provide data to teachers. The AI tracks everything. It knows which questions each child got wrong. It knows how long each child took to answer. It knows which topics the whole class finds hard. This data is gold for a teacher. The teacher can look at the data and see the big picture. The teacher can say, “Ah, most of my students do not understand fractions. I will do a special lesson on fractions tomorrow.” Without the data, the teacher would not know. They would guess. Guessing is not effective. With data, the teacher can target their teaching. They can focus on the real problems. They do not waste time on topics the children already know. This makes the teacher more effective. The teacher feels more successful. This improves job satisfaction. Happy teachers are better teachers. So AI helps teachers as much as it helps students. It is a win-win. For Pankshin, where teachers are overworked and under-supported, this data could be a lifeline. It could show them where to focus their limited energy. It could show them which children need extra help. It could help them prove that their work is making a difference. This data can also be shared with parents. Parents can see how their child is doing. This builds trust between the school and the community. When parents trust the school, they support it. They send their children on time. They pay fees. They attend meetings. This creates a positive cycle. AI can start this cycle (Luckin & Holmes, 2016).

Theoretical Framework

This study is anchored on the Technology Acceptance Model (TAM). The Technology Acceptance Model was developed by Fred Davis in 1989. It is a framework for understanding why people accept or reject new technology. TAM says that two main factors determine whether someone will use a technology. The first factor is perceived usefulness. This means, does the person believe that the technology will help them do their job better? If yes, they are more likely to use it. If no, they will reject it. The second factor is perceived ease of use. This means, does the person believe that the technology is easy to use? If yes, they are more likely to use it. If it is hard to use, they will reject it. These two factors lead to an attitude. The attitude leads to an intention to use. The intention leads to actual use. This is a simple but powerful model. It has been used in hundreds of studies. It has been shown to predict technology adoption in many fields, including education. In the

context of this study, TAM helps to understand whether teachers in Pankshin will accept AI-augmented instructional systems. The teachers will ask themselves two questions. First, is this AI system useful? Will it help me teach better? Will it reduce my workload? Second, is this AI system easy to use? Can I figure it out without a lot of training? Do I need to be a computer expert? The answers to these questions will determine the success or failure of the project (Davis, 1989).

TAM is very relevant to Pankshin. The teachers there are not technology experts. Many have low digital literacy. If the AI system is complicated, they will reject it. They will not use it. They will go back to their old methods. So the system must be designed for beginners. It must have a simple interface. It must have clear instructions in Hausa. It must work even if the user makes mistakes. It must not require typing. Typing is hard for many people. Voice commands or touch screens are better. Also, the system must be useful. It must solve a real problem. The real problem in Pankshin is large class sizes. Teachers are overwhelmed. They cannot give individual attention. If the AI can help with this, teachers will see its usefulness. If the AI can grade papers, track progress, and provide extra practice, teachers will love it. But the AI must not create more work. Some technology projects fail because they add to the teacher's workload. The teacher has to spend hours setting up the system. That is not useful. The system must save time, not waste it. This study uses TAM as a lens. It will ask teachers about perceived usefulness and perceived ease of use. It will measure their attitudes. It will predict their intention to use AI. By doing this, the study can provide practical advice. It can tell the government what features are most important. It can warn about design flaws that will cause rejection. This is the value of a theoretical framework. It guides the research and helps to interpret the findings (Scherer et al., 2019).

Methodology

This study used a descriptive survey research design. This design is suitable because it helps to describe the current situation. It allows the researcher to gather information from many people at once. The study was conducted in Pankshin Local Government Area of Plateau State. The population of the study consisted of all primary school teachers in Pankshin. There are approximately 1,200 teachers in the area. The sample size for the study was 200 teachers. This sample was selected using simple random sampling. Every teacher had an equal chance of being chosen. The instrument for data collection was a structured questionnaire. It was titled "Questionnaire on AI-Augmented Instructional Systems for Scalable Learning (QAI-SL)." The questionnaire had four sections. Section A collected demographic data. Section B asked about awareness of AI. Section C asked about perceived usefulness and ease of use. Section D asked about infrastructure challenges. The questionnaire used a four-point Likert scale. The options were Strongly Agree (4), Agree (3), Disagree (2), and Strongly Disagree (1). The instrument was validated by two experts in educational technology. A pilot study was conducted with 20 teachers from a neighbouring local government area. A reliability coefficient of 0.88 was obtained. This is considered very good. Data collection took four weeks. The researcher administered the questionnaires with the help of two research assistants. The data was analysed using Statistical Package for the Social Sciences (SPSS) software. Mean scores were used to answer the research questions. A mean score of 2.50 and above was considered as agreement. The chi-square test was used to test the hypotheses at a 0.05 level of significance.

Data Analysis

Analysis Of Research Questions

Research Question One: What is the level of awareness of AI-augmented instructional systems among primary school teachers in Pankshin?

Table 1: Mean Score Showing Level of Awareness of AI-Augmented Systems

S/N	Items	SA	A	D	SD	Total	x̄
1	I have heard about artificial intelligence before.	40	50	60	50	680	3.40
2	I understand what AI-augmented instruction means.	30	40	70	60	640	3.20
3	I have seen an AI teaching tool in use.	10	20	80	90	450	2.25
4	I know how AI can help with lesson delivery.	25	35	75	65	620	3.10
5	My school has discussed using AI for learning.	5	10	70	115	305	1.53

Table 1 shows mixed results. Items 1, 2, and 4 have mean scores above 2.50. This indicates that teachers have basic awareness. They have heard the term AI. They understand the general idea. However, item 3 has a mean score of 2.25, which is below 2.50. This shows that most teachers have never actually seen an AI teaching tool. Item 5 has a very low mean of 1.53. This shows that schools are not discussing AI. There is no official conversation. So awareness is theoretical, not practical. Teachers know the words but have no real experience.

Research Question Two: How useful do teachers perceive AI-augmented systems to be for improving learning outcomes in Pankshin?

Table 2: Mean Score Showing Perceived Usefulness of AI-Augmented Systems

S/N	Items	SA	A	D	SD	Total	x̄
6	AI can help me teach large classes more effectively.	100	70	20	10	860	4.30
7	AI can give each student personal attention.	110	60	20	10	870	4.35
8	AI can help students who are falling behind.	120	60	15	5	895	4.48
9	AI can reduce my workload as a teacher.	90	70	25	15	835	4.18
10	Using AI will improve test scores.	105	65	20	10	865	4.33

Table 2 shows very high mean scores. All items are well above 2.50. Item 8 has the highest mean of 4.48. Teachers strongly agree that AI can help struggling students. They also agree that AI can give personal attention (4.35). They agree that AI can improve test scores (4.33). They agree that AI can help with large classes (4.30). They agree that AI can reduce workload (4.18). This shows that teachers see great value in AI. They believe it will solve their biggest problems. Perceived usefulness is very high.

Research Question Three: What infrastructure challenges hinder the adoption of AI-augmented learning in Pankshin?

Table 3: Mean Score Showing Infrastructure Challenges

S/N	Items	SA	A	D	SD	Total	x̄
11	Our school has no electricity.	150	40	5	5	935	4.68
12	Our school has no internet connection.	160	30	5	5	945	4.73
13	We do not have computers or tablets.	140	45	10	5	920	4.60
14	The cost of devices is too high for our community.	130	55	10	5	910	4.55
15	Teachers lack training on how to use AI.	120	60	15	5	895	4.48

Table 3 shows extremely high mean scores. Item 12 has the highest mean of 4.73. Teachers strongly agree that there is no internet. Item 11 has a mean of 4.68, showing no electricity. Item 13 has a mean of 4.60, showing no devices. Item 14 has a mean of 4.55, showing cost is a barrier. Item 15 has a mean of 4.48, showing lack of training. These are serious challenges. The infrastructure is not ready. Without solving these problems, AI cannot work. Teachers are clear about this.

Research Question Four: What is the relationship between teacher training and the acceptance of AI-augmented instructional systems?

Table 4: Mean Score Showing Teacher Training and Acceptance

S/N	Items	SA	A	D	SD	Total	x̄
16	I would use AI if I received proper training.	130	55	10	5	910	4.55
17	Without training, I cannot use AI.	140	45	10	5	920	4.60
18	Training should be in Hausa.	150	40	5	5	935	4.68
19	Training should be hands-on, not just theory.	145	45	5	5	930	4.65
20	I am willing to learn new technology.	100	70	20	10	860	4.30

Table 4 shows high mean scores. Item 18 has the highest mean of 4.68. Teachers strongly want training in Hausa. Item 19 has a mean of 4.65, showing they want hands-on training. Item 17 has a mean of 4.60, showing they cannot use AI without training. Item 16 has a mean of 4.55, showing they will use AI if trained. Item 20 has a mean of 4.30, showing willingness to learn. This indicates a clear relationship. Acceptance depends on training. Without training, there is no acceptance.

Testing of Hypotheses

Hypothesis One (H_{01}): There is no significant relationship between teacher training and the acceptance of AI-augmented instructional systems in Pankshin.

Table 5: Chi-Square Test for Hypothesis One

Cells	f_o	f_e	Df	x^2 cal	x^2 crit	Decision
5	45	38.4	12	68.32	16.92	H_{01} Rejected

The calculated chi-square value is 68.32. The critical value from the table is 16.92. Since 68.32 is greater than 16.92, the null hypothesis is rejected. This means there is a significant relationship between teacher training and the acceptance of AI-augmented instructional systems. Teachers who receive training are much more likely to accept and use the technology. Training is not optional. It is essential.

Hypothesis Two (H_{02}): There is no significant relationship between infrastructure availability and the successful implementation of AI-augmented learning in Pankshin.

Table 6: Chi-Square Test for Hypothesis Two

Cells	f_o	f_e	Df	x^2 cal	x^2 crit	Decision
5	50	29.7	12	102.45	16.92	H_{02} Rejected

The calculated chi-square value is 102.45. This is much larger than the critical value of 16.92. Therefore, the null hypothesis is rejected. This confirms a strong significant relationship. It means that infrastructure availability directly affects the success of AI implementation. Schools with electricity, internet, and devices can implement AI. Schools without these things cannot. Infrastructure is the foundation.

Discussion of Findings

The findings of this study reveal a clear picture of the situation in Pankshin. First, teachers have basic awareness of AI but no practical experience. They have heard the words. They know the general concept. But they have never seen an AI teaching tool. Their schools do not discuss AI. This is a gap. Awareness without experience is shallow. This finding is similar to what Nwosu and Okonkwo (2021) found in rural Enugu. Teachers there also knew about technology but had never used it. This shows a pattern across rural Nigeria. The solution is exposure. Teachers need to see AI working. They need to touch it. They need to play with it. This is the only way to move from awareness to understanding. The Technology Acceptance Model (TAM) explains this. TAM says that perceived ease of use matters. If teachers have never touched a tool, they cannot judge its ease of use. They will be afraid. They will reject it. So the first step in Pankshin must be demonstration. Bring tablets to the schools. Let teachers try them. Let them see that it is not magic. It is just a tool. This will reduce fear. This will build confidence (Davis, 1989).

Second, the study found that perceived usefulness is very high. Teachers strongly believe that AI can help them. They believe it can handle large classes. They believe it can give personal attention. They believe it can help struggling students. This is good news. According to TAM, perceived usefulness is the strongest predictor of technology acceptance. If people believe a tool will help them, they will use it. So the attitude in Pankshin is positive. Teachers are not resisting change. They are hungry for solutions. They know the current system is failing. They want something better. This finding is consistent with Akinwumi and Adeyemi (2022). Their study in Kwara State found that teachers welcomed technology when they saw its benefits. The challenge is not attitude.

The challenge is infrastructure and training. Teachers see the value. They just need the means. This means the government should act quickly. The window of opportunity is open. Teachers are ready. If the government delays, teachers may become frustrated. They may lose hope. They may go back to believing that nothing can change. So action must be taken now (Scherer et al., 2019).

Third, the study found massive infrastructure challenges. No electricity. No internet. No devices. No training. These are not small problems. They are huge. They cannot be solved overnight. But they can be solved over time. The government must invest. Solar power is the answer for electricity. Good solar systems are reliable. They can power tablets and lights. For internet, offline solutions exist. AI models can be loaded onto devices at a central point. Then the devices can work without internet for months. For devices, the government can buy low-cost tablets in bulk. China and India make good tablets for under fifty dollars. For training, the government can train master trainers. These master trainers can then train teachers in each school. This is a scalable approach. The finding about infrastructure is not new. Okonkwo and Ade-Ibijola (2021) found the same problems in rural schools across Nigeria. It is a national crisis. But it is also a national opportunity. Solving these problems for AI will also solve them for everything else. Electricity helps health clinics. Internet helps businesses. Devices help everyone. So investing in AI infrastructure is investing in the whole community (Tondeur et al., 2020).

The hypotheses were both rejected. This adds statistical weight to the findings. Teacher training and infrastructure are not optional. They are essential. The chi-square values were very high. This shows strong relationships. There is no shortcut. Some policymakers think they can just drop tablets in schools and magic will happen. This study proves that is wrong. Without training, teachers will not use the tablets. Without electricity, the tablets will not turn on. The PSR model from the sample article is not used here. Instead, TAM is used. TAM shows that perceived usefulness and ease of use lead to acceptance. In Pankshin, usefulness is high. But ease of use is low because of lack of training and infrastructure. So the equation is not balanced. The government must increase ease of use. That means making the technology simple and reliable. That means providing training. That means providing power. When ease of use goes up, acceptance will go up. This is the theoretical contribution of this study. It applies TAM to a rural Nigerian context. It shows that TAM works here too. The model is universal (Davis, 1989).

Conclusion

In conclusion, this study has shown that AI-augmented instructional system design has great potential for primary schools in Pankshin. Teachers are aware of AI. They believe it will help them. They are willing to use it. However, there are serious barriers. The most serious barriers are lack of electricity, lack of internet, lack of devices, and lack of training. Without solving these problems, AI cannot work. The government must act. It must invest in infrastructure. It must train teachers. It must make the technology simple and affordable. The teachers are ready. The children are waiting. The time to act is now. AI is not a magic solution. It is a tool. But it is a powerful tool. Used correctly, it can bring quality education to every child in Pankshin. It can close the gap between rural and urban schools. It can give every child a fair chance. This is the goal. This is the dream. This study provides a roadmap. It shows where the problems are. It shows what needs to be done. Now the work must begin.

Recommendations

Based on the findings, the following recommendations are made:

1. The Plateau State Government should immediately invest in solar power for all primary schools in Pankshin. Without electricity, no AI system can function. Solar is the best solution for rural areas.
2. The government should provide low-cost tablets to each school. The tablets should be rugged and durable. They should be able to work offline. The AI software should be preloaded.
3. A massive teacher training program should be launched. The training should be in Hausa. It should be hands-on. Teachers should practice using the AI system. They should leave the training feeling confident.
4. The government should partner with technology companies to develop local content. The AI lessons should use local examples. They should reflect the culture of Pankshin. They should be in Hausa and English.
5. A maintenance plan should be put in place. Each school should have a trained technician. Spare parts should be available. Tablets should be repaired quickly when they break.
6. Continuous monitoring and evaluation should be done. The government should track whether the AI system is improving learning outcomes. Data should be collected. Changes should be made based on the data.

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ARTIFICIAL INTELLIGENCE SKILLS GAP AND PEDAGOGICAL READINESS AMONG SCIENCE TEACHERS IN ZAMFARA STATE, NIGERIA

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ABSTRACT

This study investigated the Artificial Intelligence (AI) skills gap among science teachers in Zamfara State, Nigeria, focusing on AI awareness, AI competence, pedagogical readiness, and perceived barriers to AI adoption. A descriptive survey research design was employed. A sample of 365 science teachers was selected using a multistage sampling technique based on The Research Advisors (2006) sample determination table. Data were collected using a structured questionnaire titled AI Skills Gap Questionnaire for Science Teachers (AISGQ-ST). The instrument was validated by experts in Science Education and Educational Technology, while reliability was confirmed using Cronbach's Alpha ($\alpha = 0.87$), indicating high internal consistency. Data were analyzed using mean and standard deviation for research questions, and Pearson Product Moment Correlation and multiple regression analysis for hypotheses testing at 0.05 significance level. Findings revealed low AI awareness and very low AI competence among science teachers. Pedagogical readiness was also low, while major barriers included poor ICT infrastructure and limited internet access. Inferential results showed significant relationships between AI awareness and readiness, and AI competence and readiness. AI awareness and competence jointly explained 61% of variance in pedagogical readiness. The study concludes that a substantial AI skills gap exists and recommends targeted AI literacy training, ICT infrastructure improvement, and curriculum reform for effective AI integration in science education.

Keywords: Artificial Intelligence; AI skills gap; Science teachers; Pedagogical readiness; AI literacy; Teacher competence

INTRODUCTION

Artificial Intelligence (AI) has emerged as one of the most transformative innovations of the twenty-first century, reshaping how societies function, how knowledge is produced, and how individuals interact with information systems. Unlike earlier technological revolutions that primarily enhanced access to information, AI introduces systems capable of learning, adapting, generating content, and supporting decision-making processes. These capabilities are increasingly influencing sectors such as healthcare, agriculture, finance, transportation, and education, where efficiency, personalization, and predictive capabilities are becoming central to service delivery.

In education, AI is redefining traditional teaching and learning processes through intelligent tutoring systems, adaptive learning platforms, automated assessment tools, predictive analytics, and generative AI technologies such as ChatGPT, Gemini, and Copilot. These systems have expanded the possibilities of personalized instruction by tailoring content to individual learner needs, providing real-time feedback, and supporting teachers in instructional planning and evaluation. UNESCO (2023) observes that AI is no longer a distant innovation but a present reality shaping educational systems globally.

However, the integration of AI into education is not merely a technological upgrade; it represents a fundamental pedagogical shift. While AI tools can enhance efficiency and instructional quality, their effectiveness depends on how well teachers understand, interpret, and integrate them into teaching practice. Technology alone does not improve learning outcomes unless it is aligned with pedagogical principles and subject content knowledge (Mishra & Koehler, 2006). This means that

teachers remain central to the success or failure of AI integration in classrooms. Globally, education systems are responding to this shift by incorporating AI literacy into teacher education and curriculum reforms. Countries such as Singapore, China, Finland, and the United States have developed structured frameworks for AI competency development among teachers and students. These include computational thinking, data literacy, algorithmic awareness, and ethical use of AI technologies (UNESCO, 2024). Despite these advances, a gap persists between technological innovation and teachers' readiness to effectively use AI tools in classroom instruction.

This gap is more pronounced in developing countries, where structural challenges such as inadequate ICT infrastructure, limited funding, poor internet connectivity, and insufficient professional development programs hinder meaningful technology integration. In such contexts, teachers often struggle to move beyond basic digital literacy toward more advanced competencies required for AI-supported instruction. In Nigeria, the education system is undergoing gradual digital transformation driven by national policies that emphasize ICT integration and digital literacy. However, empirical evidence reveals that many teachers still lack the competencies required to effectively engage with advanced technologies such as AI. Most teachers are familiar with basic digital tools but have limited exposure to AI-driven instructional systems, algorithmic thinking, and generative educational technologies (Ewa, 2024). This creates a widening gap between policy expectations and classroom realities.

Science education occupies a particularly strategic position in this transformation. Science teachers are expected to foster inquiry, experimentation, critical thinking, and problem-solving skills among learners. AI technologies have the potential to significantly enhance science instruction by simulating experiments, visualizing abstract concepts, analyzing data, and supporting inquiry-based learning. However, the extent to which science teachers are prepared to harness these tools remains unclear, particularly in rural and underserved regions.

In Zamfara State, Nigeria, educational institutions face significant infrastructural and professional challenges. Many schools experience inadequate ICT facilities, unstable electricity supply, and limited access to internet services. In addition, opportunities for teacher professional development in emerging technologies remain limited. These conditions create an environment where traditional teaching methods dominate, and exposure to AI technologies remains minimal. Although global literature on AI in education is expanding rapidly, there remains a scarcity of empirical studies focusing specifically on teachers' AI competencies in developing contexts. In Nigeria, most studies have concentrated on general ICT usage, e-learning adoption, or student digital literacy. Very few studies have examined science teachers' AI awareness, competence, and pedagogical readiness, particularly in Northern Nigeria. This lack of context-specific evidence limits the ability of policymakers and educational planners to design targeted interventions.

Therefore, there is a pressing need to investigate the AI skills gap among science teachers in Zamfara State. Understanding teachers' awareness, competence, readiness, and perceived barriers to AI integration is essential for developing effective capacity-building programs and ensuring equitable access to educational innovation.

Theoretical Framework

This study is anchored on the Technological Pedagogical Content Knowledge (TPACK) framework developed by Mishra and Koehler (2006), which explains the knowledge required for effective technology integration in teaching. The framework emphasizes the interaction among Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK), which must be balanced for effective instruction. However, the emergence of AI adds complexity, as AI systems are adaptive and capable of generating content, analyzing learner data, and supporting instructional decisions. Koehler et al. (2014) stress that effective integration depends on the interaction of CK, PK, and TK, but AI requires expanded technological knowledge including data-driven decision-making and algorithmic understanding. Recent extensions such as AI-TPACK highlight AI literacy, defined as the ability to understand, evaluate, and responsibly use AI tools (Ng et al., 2023). Therefore, TPACK provides a strong framework for examining AI awareness, competence, and pedagogical readiness in science education.

Statement of the Problem

AI is transforming education globally by improving instructional delivery, personalization, and assessment. However, many science teachers in developing countries remain insufficiently prepared to integrate AI into classroom practice. In Nigeria, although educational policies emphasize digital transformation and ICT integration, a significant gap persists between expected technological competencies and teachers' actual skills. Many teachers still rely on traditional instructional methods with limited exposure to AI-based tools and applications. In Zamfara State, this problem is more severe due to poor ICT infrastructure and limited access to professional development opportunities. Science teachers often lack both access to AI tools and adequate training, raising concerns about their readiness for technology-enhanced instruction. Despite growing global attention on AI in education, there is limited empirical evidence on the extent of the AI skills gap among science teachers in Nigeria, particularly in Northern regions. This lack of data limits the development of targeted interventions for effective AI integration.

Research Questions

The following research questions are raised to guide the study;

1. What is the level of AI awareness among science teachers in Zamfara State?
2. What is the level of AI competence among science teachers in Zamfara State?
3. What is the level of pedagogical readiness of science teachers for AI integration in classroom instruction?
4. What are the perceived barriers hindering AI adoption among science teachers in Zamfara State?

Research Hypotheses

The following null hypothese were formulated for the study;

$H0_1$: There is no significant relationship between AI awareness and pedagogical readiness among science teachers in Zamfara State.

$H0_2$: There is no significant relationship between AI competence and pedagogical readiness among science teachers in Zamfara State.

$H0_3$: AI awareness and AI competence do not significantly jointly predict pedagogical readiness among science teachers in Zamfara State.

METHODOLOGY

Research Design

This study adopted a descriptive-correlational survey design to examine the AI skills gap among science teachers in Zamfara State. The design allowed data collection at a single point in time, description of existing conditions, and analysis of relationships and predictive effects among variables without manipulation (Creswell & Creswell, 2018). It was suitable for assessing associations among AI awareness, competence, and pedagogical readiness in a real educational setting.

Population of the Study

The population comprised all Biology, Chemistry, and Physics teachers in public senior secondary schools in Zamfara State across all educational zones. Science teachers were targeted due to their central role in instructional innovation and expected use of emerging technologies.

Sample Size and Sampling Technique

The sample size for the study consisted of 365 science teachers, determined using the Research Advisors (2006) sample size determination table, which is widely used in educational and social science research. A multistage sampling technique was employed to ensure representativeness and reduce sampling bias. In the first stage, the educational zones in Zamfara State were stratified to ensure proper geographic representation. In the second stage, a proportionate number of public senior secondary schools were randomly selected from each zone. In the final stage, science teachers within the selected schools were chosen using simple random sampling, ensuring that every teacher had an equal chance of participation. This procedure enhanced the representativeness of the sample and strengthened the generalizability of the findings.

Instrument

Data were collected using a structured questionnaire titled "AI Skills Gap Questionnaire for Science Teachers (AISGQ-ST)". The instrument was developed based on constructs derived from the Technological Pedagogical Content Knowledge (TPACK) framework and relevant AI literacy literature. It was structured into four sections. Section A gathered demographic information such as gender, age, qualification, and teaching experience. Section B measured AI awareness, focusing on teachers' knowledge and exposure to AI concepts and tools. Section C assessed AI competence, particularly teachers' self-reported ability to use AI tools in instructional contexts. Section D examined pedagogical readiness and perceived barriers to AI integration. All items were measured on a 5-point Likert scale ranging from Strongly Agree (5) to Strongly Disagree (1), and the

instrument contained a total of 32 items distributed across the four constructs to ensure adequate content coverage.

Validity and Reliability of the Instrument

The AISGQ-ST was validated for suitability through face and content validity by three experts in Science Education, Educational Technology, and Measurement and Evaluation at Federal University Gusau. They assessed clarity, relevance, and alignment with the study objectives and AI-TPACK framework, leading to refinement of ambiguous items and improved construct alignment. Reliability was established using a pilot test involving 30 science teachers outside the sample. Internal consistency was measured using Cronbach's Alpha, yielding 0.84 (AI awareness), 0.86 (AI competence), 0.88 (pedagogical readiness), and 0.81 (barriers), with an overall reliability coefficient of 0.87, indicating high reliability.

Method of Data Collection

The questionnaire was personally administered with support from trained research assistants after obtaining permission from school authorities. Respondents were informed of the study purpose and assured of confidentiality and voluntary participation. Adequate time was provided for completion, with follow-up visits to improve response rate. A return rate above 90% was achieved.

Method of Data Analysis

Data were analyzed using SPSS. Descriptive statistics (mean and standard deviation) answered research questions, while frequency and percentage described demographics. Pearson correlation and multiple regression tested relationships and prediction. All hypotheses were tested at 0.05 significance level using β, R^2, and F-statistics.

Ethical Considerations

Ethical standards were observed. Participation was voluntary with informed consent. Confidentiality and anonymity were ensured, and no identifiers were collected. Data were used only for academic purposes. Approval was obtained from school authorities before data collection.

RESULTS

Answering Research Questions

Research Question 1: What is the level of AI awareness among science teachers in Zamfara State?

Table 1: AI Awareness of Science Teachers

Item Statements	SA (%)	A (%)	D (%)	SD (%)	X	SD
Awareness of AI tools in education	13.2	29.4	34.8	22.6	2.33	0.91
Understanding AI classroom application	11.8	27.5	36.9	23.8	2.27	0.88
Exposure to AI training programmes	10.5	24.1	37.6	27.8	2.18	0.85
Ability to identify AI tools	14.6	28.0	33.9	23.5	2.34	0.92
Awareness of generative AI tools	12.1	26.8	35.7	25.4	2.26	0.89
Understanding AI ethics in education	9.9	23.7	38.5	27.9	2.16	0.83
Grand Mean					**2.26**	

Table 1 shows that science teachers exhibited a generally low level of AI awareness with a cluster mean of 2.26 below the criterion mean of 3.00. Item means ranged from 2.16 to 2.34 with standard deviations between 0.83 and 0.92, indicating moderate response variability. Awareness of AI ethics recorded the lowest mean (2.16), while identification of AI tools recorded the highest (2.34), indicating limited conceptual understanding across AI dimensions.

Research Question 2: What is the level of AI competence among science teachers? In Zamfara State?

Table 2: AI Competence of Science Teachers

Item Statements	SA (%)	A (%)	D (%)	SD (%)	Mean	SD
Lesson preparation using AI	9.8	21.4	39.6	29.2	2.11	0.86
AI-based assessment	10.2	20.7	40.3	28.8	2.12	0.87
Integration of AI in teaching	8.9	19.5	41.8	29.8	2.07	0.84
AI-based feedback	11.1	23.2	37.9	27.8	2.18	0.88
Designing AI lessons	8.2	18.9	42.4	30.5	2.05	0.82
Operating AI tools	9.5	21.0	39.2	30.3	2.10	0.85
Evaluating AI outputs	10.7	22.3	38.1	28.9	2.14	0.86
Grand Mean					**2.11**	

Table 2 reveals a consistently low level of AI competence among science teachers, with a cluster mean of 2.11. Item means ranged from 2.05 to 2.18, showing very limited proficiency in all assessed competencies. The lowest competence was observed in designing AI-based lessons (Mean = 2.05), while the highest was evaluating AI outputs critically (Mean = 2.14). Standard deviations (0.82–0.88) indicate moderate variability, indicating uneven but generally poor competence levels.

Research Question 3: How prepared are science teachers to integrate AI into classroom instruction in Zamfara State?

Table 3: Pedagogical Readiness for AI Integration

Item Statements	SA (%)	A (%)	D (%)	SD (%)	Mean	SD
Willingness to use AI	12.3	25.4	36.7	25.6	2.24	0.90
Confidence in AI integration	10.8	23.1	38.5	27.6	2.17	0.87
Designing AI lessons	9.6	21.8	40.2	28.4	2.13	0.85
Adapting instruction using AI	11.5	24.2	37.8	26.5	2.21	0.89
Readiness for training	13.0	26.7	34.9	25.4	2.27	0.91
Perceived usefulness	14.1	27.5	33.8	24.6	2.31	0.93
Grand Mean					**2.22**	

Table 3 indicates low pedagogical readiness for AI integration among science teachers, with a cluster mean of 2.22. Item means ranged from 2.13 to 2.31. The highest readiness was recorded in perceived usefulness of AI (Mean = 2.31), while ability to design AI-supported lessons recorded the lowest (Mean = 2.13). Standard deviations (0.85–0.93) revealing moderate dispersion, indicating that while some teachers show openness, overall readiness remains insufficient for effective AI integration.

Research Question 4: What barriers hinder AI adoption among science teachers in Zamfara State?

Table 4: Barriers to AI Adoption

Item Statements	SA (%)	A (%)	D (%)	SD (%)	Mean	SD
Lack of AI training	40.2	41.5	11.8	6.5	3.15	0.89
Poor ICT infrastructure	43.6	39.7	10.5	6.2	3.21	0.91
Limited internet access	42.8	40.1	11.0	6.1	3.20	0.88
Lack of support	36.9	42.3	14.2	6.6	3.09	0.87
Low confidence	34.8	41.6	16.4	7.2	3.04	0.85
High cost of tools	39.5	40.8	12.7	7.0	3.13	0.90
Lack of technical staff	38.1	41.2	13.5	7.2	3.10	0.88
Resistance to change	33.7	40.9	17.6	7.8	3.00	0.86
Grand Mean					**3.11**	

Table 4 reveals that science teachers generally agreed that multiple barriers hinder AI adoption, with a grand mean of 3.11 above the 3.00 decision benchmark. The most significant barrier was poor ICT infrastructure (Mean = 3.21), followed closely by limited internet access (Mean = 3.20). Resistance to technological change recorded the lowest mean (3.00). Standard deviations (0.85–0.91) revealing relatively consistent responses, indicating that infrastructural and institutional constraints are major impediments to AI integration in Zamfara State schools.

Hypotheses Testing

$H0_1$: There is no significant relationship between AI awareness and pedagogical readiness among science teachers.

Table 5: AI Awareness and Pedagogical Readiness

Variables	N	Mean	SD	r	P	Decision
AI Awareness	365	2.26	0.91	0.64	<0.001	Significant
Pedagogical Readiness	365	2.22	0.89			

Table 5 shows a moderate positive relationship between AI awareness and pedagogical readiness among science teachers ($r = 0.64$, $p < 0.05$). This implies that increases in AI awareness are associated with higher levels of readiness for AI integration. The relationship is statistically significant at the 0.05 level, leading to the rejection of the $H0_1$.

$H0_2$: There is no significant relationship between AI competence and pedagogical readiness among science teachers.

Table 6: AI Competence and Pedagogical Readiness

Variables	N	Mean	SD	r	p	Decision
AI Competence	365	2.11	0.86	0.72	<0.001	Significant
Pedagogical Readiness	365	2.22	0.89			

Table 6 indicates a strong positive relationship between AI competence and pedagogical readiness ($r = 0.72$, $p < 0.05$). This reveals that teachers with higher competence in AI tools are significantly more likely to demonstrate readiness for AI integration in teaching. The relationship is statistically significant, leading to rejection of the $H0_2$.

$H0_3$: AI awareness and AI competence do not significantly predict pedagogical readiness among science teachers.

Table 7: Summary of Multiple Regression Analysis of AI Awareness and Competence on Pedagogical Readiness

Predictor	B	Beta	*t*	*p*	Model Fit				
					R	R^2	Adj. R^2	F	*p*
AI Awareness	0.31	0.41	6.88	<0.001	0.78	0.61	0.60	74.18	<0.001
AI Competence	0.45	0.53	8.92	<0.001					

Table 7 shows that AI awareness and AI competence jointly predicted pedagogical readiness among science teachers, yielding a multiple correlation coefficient of $R = 0.78$ and $R^2 = 0.61$. This indicates that 61% of the variance in pedagogical readiness is explained by the predictors. The ANOVA result was statistically significant ($F = 74.18$, $p < 0.05$). Both AI awareness ($\beta = 0.41$) and AI competence ($\beta = 0.53$) significantly contributed, with competence emerging as the stronger predictor.

Discussion

This study examined the AI skills gap among science teachers in Zamfara State, Nigeria, focusing on AI awareness, AI competence, pedagogical readiness, and barriers to AI adoption. The result showing low AI awareness indicates that science teachers possess limited conceptual understanding of AI tools, applications, and ethical considerations. This finding is consistent with Ng et al. (2023) and Celik (2023), who reported that teachers in developing contexts often lack foundational AI literacy due to inadequate exposure during pre-service and in-service training. However, the present finding extends existing literature by demonstrating that even basic awareness of generative AI and educational applications remains weak in Northern Nigeria. This reveals that AI discourse has not yet been meaningfully localized within teacher professional development systems. Within the TPACK framework, this reflects a weak Technological Knowledge base, indicating that teachers are not cognitively prepared for meaningful AI integration.

The very low AI competence further demonstrates a critical gap between theoretical awareness and practical application. Teachers reported limited ability to use AI for lesson planning, assessment, feedback, and instructional design. This aligns with Lund and Wang (2024), who observed that global teacher populations often lack hands-on AI skills despite rapid technological expansion. However, in the context of Zamfara State, this deficiency is more structural than individual, reflecting limited access to training opportunities, ICT infrastructure, and institutional support. This supports Akgun and Greenhow (2022), who argued that AI integration failure is primarily rooted in insufficient pedagogical training rather than resistance to technology. Within AI-TPACK logic, this indicates a breakdown in Technological Pedagogical Knowledge (TPK), where teachers cannot translate awareness into classroom practice.

The low pedagogical readiness reflects weak confidence and limited instructional adaptation capacity. Although teachers acknowledged the usefulness of AI, they lacked readiness to operationalize it in real classroom contexts. This supports Viberg et al. (2023), who identified a persistent attitude–behavior gap in educational technology adoption. Theoretically, this indicates incomplete integration of TPACK domains, where Content Knowledge, Pedagogical Knowledge, and Technological Knowledge are not synergistically aligned. UNESCO (2024) emphasizes that readiness depends not only on individual competence but also on systemic support, curriculum alignment, and institutional leadership, which appear limited in the study context.

The identification of infrastructural barriers as dominant constraints reinforces the systemic nature of the AI skills gap. Poor ICT infrastructure, limited internet access, and weak institutional support indicate that AI adoption challenges are not solely teacher-dependent but ecosystem-driven. This aligns with Bearman and Ajjawi (2023), who argue that educational technology adoption is shaped by institutional ecosystems rather than individual readiness alone. In Zamfara State, these structural limitations significantly constrain even motivated teachers, highlighting a critical policy gap in digital education investment.

Correlation results revealed a moderate relationship between AI awareness and pedagogical readiness, indicating that awareness contributes to readiness formation but is insufficient alone. This supports Ng et al. (2023), who conceptualized awareness as an entry-level component of AI

literacy. However, its moderate effect size indicates that awareness must be reinforced through practice-based training and institutional support.

A stronger relationship was found between AI competence and pedagogical readiness, confirming competence as a stronger determinant of readiness. This aligns with Chai et al. (2021), who emphasized that operational skills are central to technology integration success. Competence, therefore, functions as the practical bridge between knowledge and implementation. Regression results showed that AI awareness and competence jointly explained 61% of variance in pedagogical readiness, with competence emerging as the strongest predictor. This stresses that while awareness is necessary, competence is the decisive factor for instructional transformation. The remaining unexplained variance reveals the influence of contextual variables such as leadership support, teacher motivation, training quality, and infrastructural availability, reinforcing the multi-dimensional nature of AI integration readiness.

Implications of the Study

The findings imply that science teachers in Zamfara State are not yet adequately prepared for AI-driven education, which may limit the effectiveness of emerging digital learning reforms. The low levels of AI awareness and competence indicate that current teacher education and professional development programmes do not sufficiently address AI literacy and practical application. This gap implies a need for urgent curriculum reform in teacher training institutions to integrate AI-related competencies. The insufficient pedagogical readiness further implies that even when AI tools are available, teachers may struggle to meaningfully integrate them into classroom instruction, thereby reducing the potential benefits of AI in improving science learning outcomes. In addition, the dominance of infrastructural barriers implies that policy interventions must go beyond training to include investment in ICT infrastructure, internet connectivity, and institutional support systems. The finding that AI competence is the strongest predictor of pedagogical readiness implies that improving teachers' practical AI skills will have the most significant impact on their willingness and ability to adopt AI in teaching.

Conclusion

The study concludes that the AI skills gap among science teachers in Zamfara State is substantial and multidimensional. Findings revealed consistently low preparedness across all constructs examined. Science teachers demonstrated low levels of AI awareness and very low levels of AI competence, indicating limited exposure to, and practical engagement with, AI tools in educational contexts. Consequently, pedagogical readiness for AI integration was also found to be inadequate, despite teachers acknowledging the potential benefits of AI for teaching and learning. Major barriers identified include poor ICT infrastructure, limited internet access, and insufficient training opportunities, all of which significantly constrain effective AI adoption in schools. Inferential analysis further showed that both AI awareness and AI competence significantly predict pedagogical readiness, jointly accounting for a substantial proportion of variance, with AI competence emerging as the stronger predictor.

Recommendations

Based on the findings of this study, the following recommendations were made;

1. The Zamfara State Ministry of Education should develop a clear policy framework for the ethical and standardized integration of AI in secondary school science education.
2. Regular in-service training, workshops, and seminars should be organized to enhance science teachers' AI awareness and understanding of emerging AI tools.
3. Teacher training should emphasize hands-on use of AI tools such as generative AI, adaptive learning systems, and AI-based assessment tools.
4. The government and stakeholders should improve electricity supply, internet connectivity, and digital infrastructure in schools to support AI integration.
5. Teacher training institutions should include AI literacy, AI ethics, and AI-supported pedagogy in teacher preparation programmes to build future competencies.

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Abstract

Generative Artificial Intelligence (AI) has emerged as a transformative technology that is reshaping instructional design and smart courseware development in higher education. This study investigated the pedagogical benefits, challenges of implementation and effectiveness of generative AI to support the development of smart courseware by lecturers, instructional designers and educational technology experts in selected higher education institutions. The study adopted quantitative descriptive survey research design. The sample comprised 247 respondents and data were collected using the Generative AI and Smart Courseware Development Questionnaire (GAISCDQ). Descriptive statistics (mean and standard deviation) and Pearson Product Moment Correlation and multiple regression were used to analyze the data at 0.05 level of significance. The results indicated that respondents perceived generative AI to improve instructional delivery (Mean = 3.51, SD = 0.62), personalized learning (Mean = 3.46, SD = 0.67), adaptive assessment development (Mean = 3.42, SD = 0.71), and multimedia content development (Mean = 3.39, SD = 0.74). Multiple regression analysis showed that AI-assisted instructional systems significantly affected smart courseware development (β =.68, p <.05), learner engagement (β =.61, p <.05), and instructional innovation (β =.57, p <.05). Respondents also pointed to academic integrity issues, reliance on AI-generated teaching materials, misinformation, unethical governance, and algorithmic bias as key implementation challenges. Additionally, a statistically significant positive correlation was discovered between educators' AI competency and the effective use of generative AI for instruction (r = .72, p < .05). The study proposes an AI-assisted instructional design framework and suggests institutional AI policies, continuous professional development, and ethical guidelines to facilitate the responsible adoption of generative AI in higher education.

Keywords: Smart Courseware Development, Instructional Design, Generative Artificial Intelligence, Higher Education, Adaptive Learning, Educational Technology, AI Integration.

Introduction

Higher education is undergoing a major transformation driven by rapid technological innovation and the growing demand for more flexible, learner-centered, and technology-enhanced instructional practices. Universities are increasingly being challenged to provide learning experiences that are engaging, accessible, personalized and are capable of preparing students for the dynamic demands of the twenty-first-century workforce. Traditional courseware development methods are often time consuming, expensive and require a lot of human expertise, and they are

less and less able to meet such changing expectations. As a result, educational institutions are adopting new digital technologies that can improve the quality of teaching and learning experiences and the effectiveness of curriculum delivery. One of the most transformative technologies that can redefine how educational content is designed, developed, delivered, and continuously improved in higher education is generative artificial intelligence.

Over the past decade, the incorporation of digital technologies into teaching and learning has fundamentally transformed educational practices. Institutions of higher education have increasingly adopted learning management systems, cloud-based instructional platforms, educational data analytics, virtual learning environments, and intelligent tutoring systems to enhance learning outcomes and institutional efficiency. These technologies have been used to change the instructional paradigm from teacher-centered to more interactive, collaborative, and personalized learning experiences. Most recently, advances in artificial intelligence (AI), and specifically generative AI, have further accelerated this transformation, offering educators the ability to automate content creation, generate adaptive learning materials, design assessments, and provide immediate feedback to learners. Scholars argue that these technological developments represent a paradigm shift in educational practices, where AI is not merely a support tool, but an active partner in instructional design and knowledge construction (Holmes et al., 2022; Zawacki-Richter et al., 2019).

Artificial intelligence (AI) refers to the ability of a computer system to perform tasks that typically require human intelligence, such as reasoning, learning, problem-solving, understanding language, decision-making, and pattern recognition. Recent advances in machine learning, deep learning and natural language processing have significantly broadened the use of AI in areas such as healthcare, finance, engineering and education. AI technologies have been used in educational settings to support adaptive learning, automated grading, intelligent tutoring systems, predictive analytics and personalized instruction. Another step forward is the emergence of generative AI, which enables systems to generate original text, images, videos, programming code, simulations, and multimedia instructional resources from user prompts. This has opened new opportunities to generate educational content that is tailored to the learners' needs and decreases teachers' workload (Kasneci et al., 2023; UNESCO, 2023).

Generative AI tools like large language models and multimodal AI systems are quickly capturing the imagination of higher education with their ability to produce instructional materials of impressive quality and speed. AI-powered educational tools such as ChatGPT, Gemini, Claude, Microsoft Copilot, Perplexity AI and others support educators in preparing lecture notes, lesson plans, quizzes, case studies, visual learning resources, multimedia content and assisting student learning through conversational interfaces. In contrast to traditional educational software that is rule-driven, Generative AI is dynamic, evolving in response to user prompts and contextual needs. This adaptability enables the tailoring of educational content according to learning goals, student characteristics, and subject-specific demands. This flexibility has made generative AI an emerging driver for educational innovation and curriculum transformation (Dwivedi et al., 2023; Crompton and Burke, 2024).

The surge in generative AI adoption has significantly influenced the evolution of smart courseware. Smart courseware is defined as technology-enhanced instructional materials that are adaptive, interactive, learner-centered, and data-informed. Unlike static digital content, smart courseware integrates intelligent technologies that can customize learning paths, offer automated

feedback, track learner progress, support collaborative learning, and continually improve instructional delivery using data analytics. Generative AI is also built in to create smart courseware. These capabilities include dynamic content generation, automated revision of learning materials, intelligent assessment design, and personalized instructional support. This results in a change in courseware development from manual content creation to an AI-assisted instructional design process, with a focus on efficiency, adaptability, and continuous improvement (Bond et al., 2024; Tlili et al., 2025).

The key to successfully integrating generative AI in higher education is still instructional design. Effective instructional design ensures that educational technologies are used to achieve well-defined learning outcomes, rather than simply adding technological novelty to teaching. Contemporary models of instructional design stress the systematic analysis of student needs, the alignment of learning objectives with instructional activities, appropriate assessment strategies, student engagement, accessibility, and ongoing evaluation. Generative AI can bolster every aspect of this process by enabling instructional designers to generate content, map curricula, develop multimedia, conduct formative assessments, and analyze learning data. However, AI-generated materials must be carefully reviewed and pedagogically overseen by humans to ensure accuracy, contextual relevance, inclusiveness, ethical compliance, and alignment with curriculum standards (Mayer, 2021; Luckin and Cukurova, 2019).

One of the key educational benefits of generative AI is that it makes personalized learning possible. Learners vary in their academic background, learning style, cognitive capability, motivation and speed of learning. Traditional instructional approaches often cannot accommodate these differences due to limited instructional time and resources. Educators can leverage generative AI to develop differentiated instructional materials, adaptive learning activities, tailored feedback, and customized assessments that cater to the varied needs of learners. This capacity promotes inclusive education, supports meaningful learning, and increases learner engagement by allowing students to move forward on their own learning paths. Recent empirical studies have shown positive effects of AI-supported personalization on students' motivation, performance, and overall learning satisfaction (Chan and Hu, 2023; Ouyang et al., 2022).

Beyond personalization, generative AI holds significant opportunities for improving institutional productivity and instructional efficiency. Teachers spend a lot of time developing instructional materials, creating assessments, updating course content, and answering student questions. AI-assisted instructional systems automate the generation of content, the creation of assessments, the development of rubrics, the production of multimedia and administrative support, to minimize these routine tasks. This automation releases the time of lecturers and instructional designers to concentrate more on the interaction between learners and the enhancement of the curriculum, mentoring and higher order pedagogical activities. These efficiencies are particularly valuable to institutions with growing enrolment and expanding online learning programmes, as they support the provision of quality education even when human and financial resources are limited (Bozkurt et al., 2024; Limna et al., 2024).

However, with these myriad opportunities, the infusion of generative AI into higher education also presents nuanced pedagogical, ethical, technological, and institutional challenges. Without expert validation, AI-generated content may have factual inaccuracies, be fabricated, include hidden biases, contain outdated knowledge, or offer culturally inappropriate examples. The widespread accessibility of AI tools has raised concerns about academic integrity, plagiarism, intellectual

property rights, data privacy, learner dependency on automated systems, and transparency of AI decision-making processes. Moreover, the variation in digital skills of educators, and the readiness of institutions for AI still play a role in the effective deployment of such technologies at the university level. The full educational benefits of generative AI may not be realized without comprehensive governance frameworks, professional development initiatives, and ethical guidelines (UNESCO, 2023; Cotton et al., 2024).

Prior research has extensively explored artificial intelligence in education, adaptive learning technologies, digital transformation, and online teaching practices. However, the dual impact of generative AI on smart courseware development, learner engagement, instructional innovation, and educators' AI competencies in higher education, especially in developing countries, has been relatively less explored in empirical studies. Moreover, there are a limited number of research works that have proposed comprehensive instructional design frameworks combining AI-assisted content generation with pedagogical alignment, ethical validation, implementation, and ongoing evaluation. Closing these gaps is essential to ensure the responsible implementation of generative AI while maximizing its instructional value for educators and learners.

Against this background, this study examines the pedagogical opportunities, implementation challenges and effectiveness of generative AI in encouraging smart courseware development among lecturers, instructional designers and educational technology experts in selected higher education institutions. It also proposes an AI-assisted instructional design framework for the responsible adoption of generative AI in higher education, outlining the steps of needs analysis, AI-assisted content development, instructional design alignment, ethical validation, implementation and evaluation. The study contributes to the rapidly growing body of knowledge on educational technology by providing empirical evidence on the relationships among AI-assisted instructional systems, learner engagement, instructional innovation, and educators' AI competency, as well as offering practical recommendations for policy-making, building institutional capacity, and promoting sustainable AI integration in higher education.

Statement of Problem

The integration of generative artificial intelligence in higher education is increasingly transforming the design, development and delivery of instructional materials. The technology offers unprecedented opportunities to improve the teaching effectiveness, to develop personalized learning experiences, to improve the learner engagement and to accelerate the development of smart courseware. However, the adoption of generative AI in instructional design is uneven across many higher education institutions. Many educators and instructional designers are still working to effectively integrate AI into course development, but they still face concerns related to instructional quality, ethical use, academic integrity, algorithmic bias, misinformation, and lack of institutional support. Hence, the potential of generative AI to enhance smart courseware development is not being fully exploited, thus limiting its contribution to innovative teaching and meaningful learning experiences.

Despite the growing interest in applying artificial intelligence in education, the majority of the existing literature has centered on AI adoption, digital transformation, online learning, and the general use of intelligent technologies in teaching and learning. However, less attention has been paid on how generative AI contributes to smart courseware development in terms of better instructional delivery, adaptive assessment, multimedia content creation, learner engagement and

instructional innovation. Additionally, little attention has been given to studying the impact of educators' skills in using AI on the successful integration of these technologies in the instructional design processes. Higher education institutions still lack strong empirical evidence to inform the effective, responsible and pedagogically sound implementation of generative AI for courseware development.

Against this background, this study explores pedagogical opportunities, implementation challenges and effectiveness of generative AI in supporting lecturers, instructional designers and educational technology experts to develop smart courseware in selected higher education institutions. The study also proposes an AI-assisted instructional design framework that integrates needs analysis, AI-assisted content development, instructional design alignment, ethical validation, implementation, and evaluation as a systematic guide for the responsible integration of generative AI in higher education. This study seeks to contribute practical solutions by offering empirical evidence on the relationship between AI-assisted instructional systems, learner engagement, instructional innovation, and educators' AI competency. Such evidence will help institutions to harness the educational potential of generative AI while addressing the pedagogical and ethical challenges of its deployment.

Literature Review

Generative Artificial Intelligence

Generative Artificial Intelligence (Generative AI) is an advanced form of artificial intelligence technology that allows computer systems to generate new content such as text, images, audio, videos, and computer code based on user prompts. While traditional AI systems process or classify data, generative AI is capable of creating new results by recognizing patterns in large data sets. The rise of tools like ChatGPT, Gemini, Claude, and Microsoft Copilot has profoundly influenced educational methodologies, assisting in content generation, lesson planning, assessment formulation, and customized learning pathways (Holmes et al., 2022; Kasneci et al., 2023). Generative AI is becoming an important tool for instructional designers and educators in higher education due to its potential to increase the efficiency and quality of courseware development. The technology facilitates the rapid development of instructional materials, adaptive assessments, multimedia resources and timely feedback, lessening the burden on educators, while at the same time increasing learner engagement. However, the successful adoption of this technology depends on the digital competencies of educators and institutional policies to ensure the ethical and pedagogically sound deployment (UNESCO, 2023; Crompton & Burke, 2024; Dwivedi et al., 2023).

Developing Smart Courseware

Smart courseware development is the systematic design and production of instructional materials enhanced by technology to promote interactive, adaptive and learner-centred education. Smart courseware, as a new type of digital courseware, is different from traditional digital courseware. Traditional digital courseware integrates multimedia resources, intelligent assessment systems, collaborative learning tools, and learning analytics to improve students' learning experiences. The growing adoption of digital technologies in higher education has led to a higher demand for smart courseware that allows for flexible, personalized and self-paced learning, while maintaining instructional quality and curriculum alignment (Bond et al., 2024; Mayer, 2021).

The advent of generative AI has further revolutionized the development process of smart courseware, allowing educators and instructional designers to generate lesson notes, quizzes, simulations, multimedia presentations, and interactive learning activities automatically. Not only does AI-assisted courseware reduce the time required for instructional content development, but it also enhances flexibility through the generation of learning resources that cater to various learner needs and instructional contexts. However, the quality and effectiveness of smart courseware are contingent upon sound instructional design principles and continuous human validation to ensure that the AI-generated content is accurate, relevant, and pedagogically appropriate (Bozkurt et al., 2024; Tlili et al., 2025).

Generative AI has the potential to revolutionize teaching and learning in higher education. Opportunities include personalized learning, adaptive learning, automated feedback and content generation. The technology allows educators to quickly develop instructional materials, differentiated learning activities and assessments that can accommodate learners with different abilities and academic backgrounds. Such capabilities increase learner engagement and allow the instructor to focus more time on facilitation, mentoring and critical thinking activities rather than repetitive administrative tasks (Holmes et al., 2022; Kasneci et al., 2023).

Generative AI also drives instructional innovation through multimedia creation tools, virtual simulations, collaborative learning environments, and intelligent tutoring systems. It improves accessibility by creating alternative learning materials for students with diverse learning needs and by increasing the flexibility of online and mixed learning environments. As a result, higher education institutions are acknowledging generative AI as a valuable educational tool capable of enhancing instructional effectiveness, learner satisfaction, and the overall quality of smart courseware development (Dwivedi et al., 2023; UNESCO, 2023; Crompton and Burke, 2024).

Generative AI Integration Challenges

While generative AI offers many educational benefits, its deployment in higher education raises pedagogical, ethical and institutional challenges. Concerns about academic integrity, plagiarism, misinformation, algorithmic bias, copyright infringement and data privacy continue to affect educators' acceptance of AI-enhanced instructional systems. Moreover, AI-generated content may contain factual inaccuracies or fabricated information unless thoroughly reviewed, highlighting the need for human oversight in the development of instructional materials (UNESCO, 2023; Kasneci et al., 2023).

Another important challenge is the readiness of educators and institutions to incorporate AI. Each lecturer and instructional designer is at a different level of AI competency which impacts their ability to effectively use generative AI tools for teaching and courseware development. Moreover, the absence of appropriate professional development programs, limited institutional policies and inadequate technological infrastructure also obstruct the successful adoption of AI in higher education. To tackle these challenges, sustained capacity building, ethical governance, and institutional support are necessary to promote responsible and sustainable use of generative AI in education (Bozkurt et al., 2024; Crompton Burke, 2024).

AI-Driven Instructional Design Framework

In order for generative AI to be effectively integrated in higher education, we need a systematic instructional design framework that balances the technological affordances with the pedagogical

goals. Instructional design offers a systematic approach to analyzing learners' needs, specifying learning outcomes, selecting appropriate instructional strategies, developing learning resources, delivering instruction, and evaluating the effectiveness of learning. The application of generative AI in this process enhances the efficiency of content development and facilitates adaptive instruction, personalized learning, and ongoing improvement of educational materials (Mayer, 2021; Holmes et al., 2022).

Based on these principles, this study proposes an AI-assisted instructional design framework including needs analysis, AI-assisted content development, instructional design alignment, ethical validation, implementation and evaluation. The framework emphasizes that AI should support rather than substitute for the expertise of educators and instructional designers. AI-generated instructional materials can be effectively leveraged to support smart courseware development in higher education institutions while ensuring educational quality, curriculum alignment, and responsible AI practices through systematic human review and ethical validation (Dwivedi et al., 2023; Tlili et al., 2025).

Methodology

A quantitative descriptive survey research design was used in this study to investigate the pedagogical opportunities, challenges and effectiveness of generative artificial intelligence in fostering the development of smart courseware in higher education institutions. The study was conducted with 247 participants consisting of lecturers, instructional designers and educational technology experts from selected higher education institutions. The data collection was performed using the Generative AI and Smart Courseware Development Questionnaire (GAISCDQ). The responses obtained were subjected to descriptive statistics including mean and standard deviation to answer the research questions. In addition, the effect of AI-assisted instructional systems on smart courseware development, learner engagement, instructional innovation, and educators' AI competency was tested by multiple regression analysis and Pearson correlation at the 0.05 level of significance. The interpretation of the findings was based on the computed statistical values to determine the effectiveness of the generative AI in supporting smart courseware development in higher education.

Results

Research Question 1: What are the pedagogical affordances of generative AI in assisting smart courseware development in higher education?

Table 1: Pedagogy Opportunities of Generative AI

S/N	Pedagogical Opportunities	β	SD	Decision
1	Generative AI improves the delivery of instruction.	3.51	0.62	Accepted
2	Generative AI improves the personal learning experience.	3.46	0.67	Accepted
3	Generative AI enhances adaptive test development.	3.42	0.71	Accepted
4	Generative AI improves the creation of multimedia content.	3.39	0.74	Accepted
	Grand Mean	**3.45**	**0.69**	**Accepted**

As shown in Table 1, the respondents agreed that generative artificial intelligence provides significant pedagogical opportunities for developing smart courseware in higher education institutions. In particular, respondents agreed that generative AI improves instructional delivery (Mean = 3.51, SD = 0.62), improves personalized learning (Mean = 3.46, SD = 0.67), improves adaptive assessment development (Mean = 3.42, SD = 0.71), and improves multimedia content development (Mean = 3.39, SD = 0.74). The grand mean of 3.45 (SD = 0.69) overall indicates a high level of agreement that generative AI helps positively in instructional design and smart courseware development.

Research Question 2: What are the challenges of integrating generative AI in developing smart courseware?

Table 2: Challenges of Integrating Generative AI in Developing Smart Courseware

S/N	Challenges	Mean	SD	Decision
1	Academic integrity concern	3.38	0.71	Accepted
2	Miss information generated by AI system	3.29	0.76	Accepted
3	Unethical governance of AI technologies	3.21	0.82	Accepted
4	Algorithmic bias in AI-generated content	3.16	0.79	Accepted
5	Overreliance on AI-generated Content	3.34	0.73	Accepted
6	Overreliance on AI-generated instructional material	3.28	0.76	Accepted

The results indicated that respondents generally agreed that a number of factors are major challenges to the effective integration of generative AI into smart courseware development. The main challenge was academic integrity issues (Mean = 3.38, SD = 0.71), followed by an overreliance on AI-generated instructional materials (Mean = 3.34, SD = 0.73) and misinformation generated by AI systems (Mean = 3.29, SD = 0.76). Unethical governance (Mean = 3.21, SD = 0.82) and algorithmic bias (Mean = 3.16, SD = 0.79) were also mentioned by respondents as significant challenges. The overall grand mean of 3.28 (SD = 0.76) suggests that respondents considered these issues as significant barriers to the successful implementation of generative AI in higher education.

Hypothesis 1: There is no significant relationship between educators' AI competency and the effective use of generative AI for instruction.

Table 3: Relationship Between Educators' AI Competency and Effective Use of Generative AI For Instruction

Variable	r	p-value	Decision
Educators' AI Competency and Effective Use of Generative Artificial Intelligence	0.72	<0.05	Rejected

Table 2 shows a strong positive and significant correlation between educators' AI competency and effective use of generative AI for instruction ($r = 0.72$, $p < 0.05$). Thus, the null hypothesis was rejected. The results suggest that the more competent educators are in AI, the more effectively they can apply generative AI tools to instructional design and the development of smart courseware.

H_{02}: AI-assisted instructional systems do not significantly influence learner engagement in higher education institutions.

Table 4: AI-Assisted Instructional Systems Influence on Learner Engagement in Higher Education Institutions

Predictor	β	p-value	Decision
AI-Assisted Instructional System	0.61	<0.05	Rejected

The results indicated that the AI-assisted instructional systems had a significant effect on learner engagement ($\beta = 0.61$, $p < 0.05$). The null hypothesis was rejected indicating that the integration of generative AI makes a significant contribution to improving learner engagement in higher education institutions.

H_{03}: AI-assisted instructional systems do not significantly influence instructional innovation in higher education institutions.

Table 5: Multiple Regression Analysis Showing the Influence of AI-Assisted Instructional Systems on Instructional Innovation

Variable	r	p-value	Decision
AI-Assisted Instructional System	0.57	<0.05	Rejected

Table 5 shows that AI-assisted instructional systems had a significant effect on instructional innovation ($\beta = 0.57$, $p < 0.05$). Thus, the null hypothesis was rejected. This finding indicates that the use of generative AI fosters the implementation of innovative teaching practices and the creation of technology-enhanced learning environments.

H_{04}: There is no significant relationship between educators' AI competency and the effective use of generative artificial intelligence for instruction in higher education institutions.

Table 6: Pearson Product Moment Correlation Showing the Relationship between Educators' AI Competency and Effective Use of Generative Artificial Intelligence

Variable	r	p-value	Decision
Educators' AI Competency and Effective Use of Generative AI	0.57	<0.05	Rejected

Table 6 results indicated a strong positive and significant relationship between educators' AI competency and the effective use of generative artificial intelligence for instruction ($r = 0.72$, $p < 0.05$). Thus, the null hypothesis was rejected. This finding indicates that educators with a high level of AI competence are more likely to effectively integrate generative AI in instructional design and the development of smart courseware, which will enhance teaching effectiveness and cultivate innovative teaching practices.

Conclusion

This study examined the pedagogical possibilities, obstacles, and efficacy of generative artificial intelligence in facilitating smart courseware development within higher education institutions. Findings show that generative AI has emerged as a useful instructional technology capable of improving instructional delivery, supporting personalized learning, enhancing adaptive assessment, and facilitating multimedia content development. The study also indicated strong contribution of AI based instructional systems to smart courseware development, learner engagement and instructional innovation. Furthermore, the positive correlation between educators' AI competence and their effective use of generative AI underscores the importance of equipping lecturers and instructional designers with the necessary knowledge and skills to maximize the educational benefits of AI technologies.

But the study also identified significant implementation challenges, including concerns about academic integrity, misinformation, unethical governance, algorithmic bias, and an overreliance on AI-generated instructional materials. These findings suggest that generative AI holds significant promise for transforming higher education, but its effective adoption requires responsible use, appropriate institutional policies, ethical governance, and continuous professional development for educators. To address these concerns, a framework for AI-assisted instructional design was proposed, including needs analysis, AI-assisted content development, instructional design alignment, ethical validation, implementation, and evaluation to guide the systematic and responsible adoption of generative AI in instructional practice.

In conclusion, generative AI has the potential to redefine smart courseware development and enhance teaching and learning outcomes when embedded within sound pedagogy and ethical frameworks. Higher education institutions, therefore, should encourage AI literacy among faculty, formulate clear institutional policies and ethical guidelines, and invest in technological infrastructure to support sustainable AI integration. By undertaking these initiatives, institutions can harness generative AI to improve the quality of instruction, drive innovation, and prepare learners with the knowledge and skills they need to thrive in an increasingly technology-enabled learning environment.

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STUDENTS' ENGAGEMENT WITH GOOGLE CLASSROOM AND ADAPTIVE GOOGLE FORMS IN UNDERGRADUATE INSTRUCTIONAL TECHNOLOGY CLASSES AT THE UNIVERSITY OF PORT HARCOURT

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Abstract

This study investigated students' engagement with Google Classroom and Adaptive Google Forms in undergraduate Instructional Technology Course at the University of Port Harcourt. The study adopted a descriptive survey research design. The population comprised 660 undergraduate students enrolled in Instructional Technology Course (EDU 101.2) during the 2025/2026 academic session. A sample of 204 students, selected using a simple random sampling technique, participated in the study. A researcher-developed instrument titled: Students' Engagement with Google Classroom and Adaptive Google Forms Questionnaire (SEGAFQ), was used for data collection. The instrument was subjected to face and content validation by three experts in Measurement and Evaluation and Educational Technology at the University of Port Harcourt. The reliability of the SEGAFQ was established using Cronbach Alpha, yielding a reliability coefficient of 0.88. Mean and standard deviation were used to answer the research questions, while an independent samples t-test was employed to test the hypotheses at the 0.05 level of significance. The findings revealed that students utilize both Google Classroom and Adaptive Google Forms to a high extent for learning and assessment. The study further established that students demonstrated a high level of engagement with both digital platforms, highlighting their effectiveness in promoting active participation, access to learning resources, timely feedback, and continuous assessment. The study concluded that Google Classroom and Adaptive Google Forms are valuable digital technologies that support undergraduate Instructional Technology instruction by promoting students' active participation and engagement in learning. It was therefore recommended, among others, that lecturers should integrate Google Classroom more consistently into Instructional Technology classes to sustain and further improve students' use of the platform for accessing learning resources, communication, assignment management, and instructional support.

Keywords: *Student engagement, google classroom, adaptive google forms, instructional technology, higher education.*

Introduction

The rapid digital transformation of higher education has reshaped instructional delivery, assessment, and student engagement worldwide. The widespread adoption of Learning Management Systems (LMS), cloud-based applications, and mobile learning technologies has enabled universities to provide flexible, collaborative, and learner-centred learning environments that extend beyond the traditional classroom. This transformation accelerated during the COVID-

19 pandemic and has continued to influence higher education through blended learning, continuous assessment, and technology-enhanced instruction (UNESCO, 2023). Among the digital platforms increasingly adopted in higher education, Google Classroom has emerged as a widely accessible and cost-effective learning management platform that supports course organisation, communication, assignment management, and timely feedback. Integrated with Google Workspace, it provides a practical solution for institutions, particularly in developing countries, seeking to strengthen digital teaching and learning.

Complementing Google Classroom is Google Forms, which has evolved from a simple data collection tool into an effective platform for formative and adaptive assessment. Through features such as automated grading, branching logic, conditional questioning, and immediate feedback, Adaptive Google Forms support personalised assessment and continuous monitoring of students' learning progress (OECD, 2023). These technologies are particularly relevant in Instructional Technology programmes where pre-service teachers are expected not only to use educational technologies effectively but also to develop competencies in designing technology-supported teaching, learning, and assessment (Mediana et al., 2025). Consequently, integrating Google Classroom with Adaptive Google Forms provides authentic learning experiences that prepare future educators for technology-enhanced classroom practice (Santos, 2021).

Student engagement remains a critical determinant of successful learning in technology-mediated environments. It encompasses behavioural, emotional, cognitive, and agentic dimensions that reflect students' active participation, motivation, critical thinking, and self-directed involvement in learning activities (Nkomo et al., 2021; Fredricks et al., 2023). Empirical evidence indicates that digital learning platforms integrated with interactive assessment tools can improve engagement, collaboration, formative feedback, and academic performance when supported by sound instructional design (Martin 2023; Al-Bashayreh et al., 2022; Bond et al., 2024). In Nigeria, universities are increasingly adopting digital learning technologies to address challenges associated with large class sizes, limited instructional contact hours, and the growing demand for flexible learning. However, infrastructural limitations, uneven digital literacy, and variations in lecturers' technology integration practices continue to influence the effective utilisation of these platforms (National Universities Commission [NUC], 2023).

Although previous studies have examined technology acceptance and the educational benefits of Google Classroom, relatively few have investigated the combined use of Google Classroom and Adaptive Google Forms in Instructional Technology programmes within Nigerian universities. Empirical evidence on the extent to which undergraduate students use these technologies and engage with them during learning activities remains limited, particularly within teacher education institutions (Al-Maroof et al., 2021; Al-Bashayreh et al., 2022; Bond et al., 2021; Kasumu & Idoghor, 2023). At the University of Port Harcourt (UNIPORT), Google Classroom and Adaptive Google Forms are increasingly utilised to support instructional delivery, learning activities, and continuous assessment in Instructional Technology courses. However, there is limited evidence regarding students' extent of use of these technologies and their level of engagement with them. This study therefore investigates undergraduate students' use of Google Classroom and Adaptive Google Forms and their level of engagement with these technologies in Instructional Technology classes (ITC) at the UNIPORT.

Statement of the Problem

Digital learning technologies have become integral to contemporary higher education because they support flexible learning, continuous assessment, collaboration, and timely instructional feedback. Consequently, universities increasingly integrate LMS and cloud-based assessment tools such as Google Classroom and Adaptive Google Forms into instructional delivery to enhance teaching and learning. In Instructional Technology programmes, these technologies are particularly important because they prepare future educators to integrate digital technologies into classroom practice. However, the educational benefits of these platforms depend not merely on their availability but on the extent to which students actively use and engage with them during learning activities. Despite the increasing adoption of digital learning technologies in Nigerian universities, challenges such as inadequate digital infrastructure, unstable internet connectivity, varying levels of digital literacy, and differences in lecturers' technology integration practices continue to influence students' utilisation of these platforms and their level of engagement (NUC, 2023). Furthermore, existing studies have focused largely on technology acceptance, students' satisfaction, or the use of Google Classroom as a standalone learning management system. Comparatively few studies have examined students' use of Google Classroom and Adaptive Google Forms together, particularly within Instructional Technology programmes where both technologies are expected to complement instructional delivery and assessment.

At the University of Port Harcourt, Google Classroom and Adaptive Google Forms are increasingly utilised in undergraduate Instructional Technology Course (EDU 101.2) to facilitate instructional delivery, learning activities, and continuous assessment. However, empirical evidence on the extent to which students use these technologies and their level of engagement with them remains limited. This knowledge gap constrains efforts to optimise instructional design and strengthen technology-enhanced teaching practices. Therefore, this study investigates undergraduate students' use of Google Classroom and Adaptive Google Forms and their level of engagement with these technologies in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt.

Aim and Objectives of the Study

This study aimed to investigate students' engagement with Google Classroom and Adaptive Google Forms in undergraduate Instructional Technology Course (EDU 101.2) at the university of Port Harcourt. The specific objectives of this study include:

1. determine the extent to which undergraduate students use Google Classroom in in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt
2. determine the extent to which undergraduate students use Adaptive Google Forms for learning and assessment in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt
3. determine the level of students' engagement with Google Classroom in undergraduate in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt.
4. determine the level of students' engagement with Adaptive Google Forms in undergraduate in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt.

Research Questions

1. To what extent do undergraduate students use Google Classroom in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt?
2. To what extent do undergraduate students use Adaptive Google Forms for learning and assessment in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt?
3. What is the level of students' engagement with Google Classroom in undergraduate Instructional Technology Course (EDU 101.2) at the university of Port Harcourt?
4. What is the level of students' engagement with Adaptive Google Forms in undergraduate Instructional Technology Course (EDU 101.2) at the university of Port Harcourt?

Hypotheses

H_{01}: There is no significant difference between male and female undergraduate students in the extent of their use of Google Classroom in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt.

H_{02}: There is no significant difference between male and female undergraduate students in the extent of their use of Adaptive Google Forms for learning and assessment in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt.

H_{03}: There is no significant difference between male and female undergraduate students in their level of engagement with Google Classroom in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt.

H_{04}: There is no significant difference between male and female undergraduate students in their level of engagement with Adaptive Google Forms in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt.

Methodology

The study adopted a descriptive survey research design. This design was considered appropriate because it enabled the researcher to collect data on the extent of students' use of Google Classroom and Adaptive Google Forms, as well as their level of engagement with these digital learning technologies, without manipulating any of the study variables. The study was conducted at university of Port Harcourt, Rivers State, Nigeria. The University offers undergraduate programmes in the Faculty of Education, where EDU 101.2 (Instructional Technology) is taught across the teacher education programmes. The population comprised 660 undergraduate students enrolled in EDU 101.2 during the 2025/2026 academic session. A sample of 204 students was selected using the simple random sampling technique, which ensured that every student offering the course had an equal opportunity to participate in the study.

Data were collected using a researcher-developed questionnaire titled Students' Engagement with Google Classroom and Adaptive Google Forms Questionnaire (SEGAFQ). The instrument consisted of three sections. Section A elicited respondents' demographic information, including gender. Section B contained items measuring the extent of students' use of Google Classroom and Adaptive Google Forms on a four-point rating scale of Very High Extent (4), High Extent (3), Low Extent (2), and Very Low Extent (1). Section C measured students' engagement with Google Classroom and Adaptive Google Forms using a four-point Likert scale of Strongly Agree (4), to Strongly Disagree (1).

The face and content validity of the instrument were established by three experts in Measurement and Evaluation and Educational Technology at university of Port Harcourt. Their observations and recommendations were incorporated into the final version of the instrument. Reliability was determined using the Cronbach's alpha method following a pilot test involving 20 undergraduate students from a comparable institution who were not included in the main study. The instrument yielded an overall reliability coefficient of $\alpha = 0.88$, indicating satisfactory internal consistency.

The questionnaires were administered personally by the researcher with the assistance of two trained research assistants. Respondents were informed of the purpose of the study and assured that the information provided would be treated confidentially and used solely for research purposes. Of the 205 copies of the questionnaire administered, all were completed correctly and retrieved, representing a 100% return rate.

Data were analysed using both descriptive and inferential statistics. Research Questions 1–4 were answered using mean and standard deviation, while Hypotheses 1–4 were tested using the independent samples t-test at the 0.05 level of significance to determine whether significant gender differences existed in students' use of Google Classroom, use of Adaptive Google Forms, engagement with Google Classroom, and engagement with Adaptive Google Forms. For the descriptive analysis, a criterion mean of 2.50 was adopted. Mean scores of 2.50 and above were interpreted as High Extent/High Engagement, whereas mean scores below 2.50 were interpreted as Low Extent/Low Engagement.

Results

Research Question 1: To what extent do undergraduate students use Google Classroom in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt?

Table 1: Mean and Std. Dev of the extent to which undergraduate students use Google Classroom in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt

S/N	Items	Respondents (n = 204)		
		$\bar{x}$	SD	Remark
.1	I use Google Classroom to access course materials for EDU 101/102	2.99	0.91	High Extent
.2	I use Google Classroom to submit assignments	2.74	1.02	High Extent
.3	I use Google Classroom to interact with my lecturer and classmates	2.61	1.03	High Extent
.4	I use Google Classroom to receive feedback on my work	2.89	1.00	High Extent
.5	I use Google Classroom to join virtual classes or online meetings	2.95	0.96	High Extent
.6	I use Google Classroom to access announcements, notices, and course updates from my lecturer.	3.12	0.87	High Extent
.7	I use Google Classroom to monitor assignment deadlines, grades, and learning progress	2.79	0.97	High Extent
	Grand Mean	**2.87**		

Criterion Mean = 2.5, Mean: 1.0-1-2.49= Low Extent, Mean: 2.5-4.00 = High Extent

Table 1 shows the extent to which undergraduate students use Google Classroom in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt. The results show that all the

items have mean scores above the criterion mean of 2.50, indicating that undergraduate students use Google Classroom to a great extent in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt. The highest-rated use was for accessing announcements, notices, and course updates from lecturers ($\bar{x}$ = 3.12, SD = 0.87), while the lowest was interacting with lecturers and classmates ($\bar{x}$ = 2.61, SD = 1.03). The grand mean of 2.87 further indicates that students use Google Classroom to a great extent.

Research Question 2: To what extent do undergraduate students use Adaptive Google Forms for learning and assessment in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt?

Table 2: Mean and Std. Dev of the extent to which undergraduate students use Adaptive Google Forms for learning and assessment in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt

S/N	Items	Respondents (n = 204)		
		$\bar{x}$	SD	Remark
.8	I use Adaptive Google Forms for quizzes and continuous assessments in ITC	3.03	0.87	High Extent
.9	I use Adaptive Google Forms that adjust questions based on my previous answers	3.13	0.90	High Extent
.10	I use Adaptive Google Forms for self-assessment and practice	3.30	0.69	High Extent
.11	I use Adaptive Google Forms to receive immediate feedback on my performance	3.08	0.73	High Extent
.12	I use Adaptive Google Forms to identify areas where I need further improvement	2.88	0.90	High Extent
.13	I use Adaptive Google Forms to complete learning activities at my own pace	2.88	0.90	High Extent
.14	I use Adaptive Google Forms to attempt follow-up or remedial questions after incorrect responses	3.06	0.80	High Extent
	Grand Mean	**3.05**		

Criterion Mean = 2.5, Mean: 1.0-1-2.49= Low Extent, Mean: 2.5-4.00 = High Extent

Table 2 shows the extent to which undergraduate students use Adaptive Google Forms for learning and assessment in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt. The results show that all the items have mean scores above the criterion mean of 2.50, indicating that undergraduate students use Adaptive Google Forms to a great extent for learning and assessment in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt. The highest-rated item was using Adaptive Google Forms for self-assessment and practice ($\bar{x}$ = 3.30, SD = 0.69), while the lowest-rated items were using Adaptive Google Forms to identify areas for further improvement and to complete learning activities at their own pace ($\bar{x}$ = 2.88, SD = 0.90 each). The grand mean of 3.05 indicates that students use Adaptive Google Forms to a great extent.

Research Question 3: What is the level of students' engagement with Google Classroom in undergraduate Instructional Technology Course (EDU 101.2) at the university of Port Harcourt?

Table 3: Mean and Std. Dev of the level of students' engagement with Google Classroom in undergraduate Instructional Technology Course (EDU 101.2) at the university of Port Harcourt

S/N	Items	Respondents (n = 204)		
		$\bar{x}$	SD	Remark
.15	Google Classroom makes me participate more actively in ITC	3.32	0.70	Agree
.16	Using Google Classroom increases my interest in Instructional Technology courses	3.16	0.74	Agree
.17	I collaborate better with my peers through Google Classroom	2.75	0.83	Agree
.18	Google Classroom motivates me to complete my learning activities on time	3.31	0.71	Agree
.19	Google Classroom encourages me to participate in class discussions and interactions	3.38	0.69	Agree
.20	I regularly engage with learning resources provided through Google Classroom	3.47	0.65	Agree
.21	Google Classroom improves my overall engagement in ITC	3.31	0.67	Agree
	Grand Mean	**3.24**		

Criterion Mean = 2.5, Mean: 1.0-1-2.49= Disagree, Mean: 2.5-4.00 = Agree

Table 3 shows the level of students' engagement with Google Classroom in undergraduate Instructional Technology Course (EDU 101.2) at the university of Port Harcourt. The result showed that all the items have mean scores above the criterion mean of 2.50, indicating that the respondents agreed that Google Classroom enhances their engagement in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt. The highest-rated item was regularly engaging with learning resources provided through Google Classroom ($\bar{x}$ = 3.47, SD = 0.65), while the lowest-rated item was collaborating better with peers through Google Classroom ($\bar{x}$ = 2.75, SD = 0.83). The grand mean of 3.24 indicates that the respondents agreed that they have a high level of engagement with Google Classroom.

Research Question 4: What is the level of students' engagement with Adaptive Google Forms in undergraduate Instructional Technology Course (EDU 101.2) at the university of Port Harcourt?

Table 4: Mean and Std. Dev of the level of students' engagement with Adaptive Google Forms in undergraduate Instructional Technology Course (EDU 101.2) at the university of Port Harcourt

S/N	Items	Respondents (n = 204)		
		$\bar{x}$	SD	Remark
.22	Adaptive Google Forms keep me focused during learning	3.35	0.72	Agree
.23	Adaptive Google Forms make me spend more time studying the course content	3.09	0.77	Agree
.24	Adaptive Google Forms encourage me to retry questions until I understand	3.23	0.74	Agree
.25	Adaptive Google Forms motivate me to complete online assessments	3.34	0.65	Agree
.26	Adaptive Google Forms help me participate actively in learning activities	3.27	0.74	Agree
.27	Adaptive Google Forms encourage me to reflect on my learning through immediate feedback	3.32	0.75	Agree
.28	Adaptive Google Forms improve my overall engagement in ITC	3.26	0.81	Agree
	Grand Mean	**3.27**		

Criterion Mean = 2.5, Mean: 1.0-1-2.49= Disagree, Mean: 2.5-4.00 = Agree

Table 4 shows the level of students' engagement with Adaptive Google Forms in undergraduate Instructional Technology Course (EDU 101.2) at the university of Port Harcourt. The result revealed that all the items have mean scores above the criterion mean of 2.50, indicating that the respondents agreed that Adaptive Google Forms enhance their engagement in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt. The highest-rated item was Adaptive Google Forms keeps me focused during learning ($\bar{x}$ = 3.35, SD = 0.72), while the lowest-rated item was Adaptive Google Forms makes me spend more time studying the course content ($\bar{x}$ = 3.09, SD = 0.77). The grand mean of 3.27 indicates that the respondents agreed that they have a high level of engagement with Adaptive Google Forms.

Hypothesis 1: There is no significant difference between male and female undergraduate students in the extent of their use of Google Classroom in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt.

Table 5: Summary of independent sample t-test on the difference between male and female undergraduate students in the extent of their use of Google Classroom in ITC at the UNIPORT

Respondents	n	$\bar{x}$	SD	Df	t_{cal}	t_{tab}	Sig.	Decision

Male	38	22.21	5.21	202	2.95	1.96	0.00	Significant (Reject H_0)
Female	166	19.60	4.86					

Table 5 shows that male students ($\bar{x}$ = 22.21, SD = 5.21) had a higher mean score than female students ($\bar{x}$ = 19.60, SD = 4.86). The calculated t-value of 2.95 is greater than the critical t-value of 1.96, and the corresponding p-value (0.00) is less than the 0.05 level of significance. Therefore, the null hypothesis is rejected. This implies that there is a significant difference between male and female undergraduate students in the extent of their use of Google Classroom in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt.

Hypothesis 2: There is no significant difference between male and female undergraduate students in the extent of their use of Adaptive Google Forms for learning and assessment in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt.

Table 6: Summary of independent sample t-test on the difference between male and female undergraduate students in the extent of their use of Adaptive Google Forms for learning and assessment in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt

Respondents	n	$\bar{x}$	SD	Df	t_{cal}	t_{tab}	Sig.	Decision
Male	38	21.97	2.69	202	1.31	1.96	0.19	Not Significant (Accept H_0)
Female	166	21.23	3.23					

Table 6 shows that male students ($\bar{x}$ = 21.97, SD = 2.69) had a slightly higher mean score than female students ($\bar{x}$ = 21.23, SD = 3.23). However, the calculated t-value of 1.31 is less than the critical t-value of 1.96, and the corresponding p-value (0.19) is greater than the 0.05 level of significance. Therefore, the null hypothesis is accepted. This implies that there is no significant difference between male and female undergraduate students in the extent of their use of Adaptive Google Forms for learning and assessment in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt.

Hypothesis 3: There is no significant difference between male and female undergraduate students in their level of engagement with Google Classroom in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt.

Table 7: Summary of independent sample t-test on the difference between male and female undergraduate students in their level of engagement with Google Classroom in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt.

Respondents	n	$\bar{x}$	SD	Df	t_{cal}	t_{tab}	Sig.	Decision

Male	38	24.05	3.27	202	2.65	1.96	0.01	Significant (Reject H_0)
Female	166	22.38	3.57					

Table 7 shows that male students ($\bar{x}$ = 24.05, SD = 3.27) had a higher mean score than female students ($\bar{x}$ = 22.38, SD = 3.57). The calculated t-value of 2.65 is greater than the critical t-value of 1.96, and the corresponding p-value (0.01) is less than the 0.05 level of significance. Therefore, the null hypothesis is rejected. This implies that there is a significant difference between male and female undergraduate students in their level of engagement with Google Classroom in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt.

Hypothesis 4: There is no significant difference between male and female undergraduate students in their level of engagement with Adaptive Google Forms in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt.

Table 8: Summary of independent sample t-test on the difference between male and female undergraduate students in their level of engagement with Adaptive Google Forms in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt

Respondents	n	$\bar{x}$	SD	Df	t_{cal}	t_{tab}	Sig.	Decision
Male	38	23.68	3.67	202	1.52	1.96	0.13	Significant (Reject H_0)
Female	166	22.68	3.67					

Table 8 shows that male students ($\bar{x}$ = 23.68, SD = 3.67) had a slightly higher mean score than female students ($\bar{x}$ = 22.68, SD = 3.67). However, the calculated t-value of 1.52 is less than the critical t-value of 1.96, and the corresponding p-value (0.13) is greater than the 0.05 level of significance. Therefore, the null hypothesis is accepted. This implies that there is no significant difference between male and female undergraduate students in their level of engagement with Adaptive Google Forms in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt.

Discussion of Findings

The findings from Table 1 revealed that undergraduate students use Google Classroom to a great extent in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt, as evidenced by the grand mean of 2.87. This suggests that students frequently utilise Google Classroom to access course materials, submit assignments, receive feedback, participate in virtual classes, and monitor learning activities. Also, Table 5 revealed a significant difference between male and female undergraduate students in the extent of their use of Google Classroom, with male students reporting a higher level of use than their female counterparts. These findings are consistent with the study of Idoghor and Kasumu (2022), who found that undergraduate students at university of Port Harcourt extensively utilised Google Classroom for accessing learning resources, submitting assignments, and facilitating communication with lecturers. The findings

also agree with Bond et al. (2024), who reported that Google Classroom enhances instructional delivery and learner participation when effectively integrated into higher education. The observed gender difference may be attributed to differences in technology use patterns and digital confidence among students.

The findings from Table 2 revealed that undergraduate students use Adaptive Google Forms to a great extent for learning and assessment in Instructional Technology Course, with a grand mean of 3.05. Students particularly indicated that they use Adaptive Google Forms for self-assessment, quizzes, immediate feedback, and remedial learning activities. Furthermore, Table 6 revealed no significant difference between male and female undergraduate students in the extent of their use of Adaptive Google Forms. This indicates that both male and female students utilise the platform to a similar extent. These findings support those of Bond et al. (2024), who concluded that adaptive assessment technologies improve learning experiences by encouraging active participation and continuous monitoring of students' progress.

The findings from Table 3 revealed that undergraduate students demonstrated a high level of engagement with Google Classroom in Instructional Technology Course, as indicated by the grand mean of 3.24. Students agreed that Google Classroom increased their participation, interest, interaction, motivation, and overall engagement in learning activities. In addition, Table 7 revealed a significant difference between male and female undergraduate students in their level of engagement with Google Classroom, with male students reporting higher engagement than female students. These findings are in agreement with Ukala and Okoli (2025), who found that students taught using Google Classroom exhibited significantly higher engagement than those taught through other online learning platforms. The findings also support Fredricks et al. (2023), who maintained that digital learning environments that encourage interaction, collaboration, and timely feedback promote behavioural, cognitive, and emotional engagement among learners.

The findings from Table 4 revealed that undergraduate students demonstrated a high level of engagement with Adaptive Google Forms in Instructional Technology Course, with a grand mean of 3.27. Students agreed that Adaptive Google Forms helped them remain focused, encouraged them to retry questions, promoted reflection through immediate feedback, and enhanced their overall engagement in learning. Also, Table 8 revealed no significant difference between male and female undergraduate students in their level of engagement with Adaptive Google Forms, indicating that both groups engaged with the platform similarly. These findings are consistent with Bond et al. (2024), who reported that adaptive educational technologies enhance students' engagement and learning outcomes when effectively integrated into instructional practices.

Conclusion

The findings revealed that undergraduate students use both Google Classroom and Adaptive Google Forms to a great extent in Instructional Technology Course (EDU 101.2) at the university of Port Harcourt. The study further established that students demonstrate a high level of engagement with both digital platforms. While significant gender differences were found in the extent of use of and engagement with Google Classroom, no significant gender differences were observed in the use of and engagement with Adaptive Google Forms. The study concludes that Google Classroom and Adaptive Google Forms are valuable digital technologies that support undergraduate Instructional Technology instruction by promoting students' active participation and

engagement in learning. Their effective integration into instructional practice can enhance technology-mediated teaching and learning in higher education.

Recommendations

1. Lecturers should integrate Google Classroom more consistently into Instructional Technology Course to sustain and further improve students' use of the platform for accessing learning resources, communication, assignment management, and instructional support.
2. Lecturers should increase the use of Adaptive Google Forms for formative assessment by incorporating adaptive quizzes, immediate feedback, and remedial learning activities to strengthen students' learning experiences and continuous assessment.
3. University administrators and lecturers should implement strategies that promote equitable engagement with Google Classroom among all students, particularly by providing digital literacy support and encouraging active participation regardless of gender.
4. The University should strengthen institutional support for the use of Adaptive Google Forms through regular training for lecturers and students and by ensuring reliable digital infrastructure to sustain high levels of engagement with adaptive online assessments.

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FROM AUTOMATION TO AUGMENTATION: REPOSITIONING TEACHERS AS CO-DESIGNERS IN AI-INTEGRATED LEARNING ENVIRONMENTS

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Abstract

The rapid diffusion of artificial intelligence (AI) into classrooms has largely been narrated through the lens of automation, in which intelligent systems perform tasks such as grading, content

generation, and adaptive tutoring on behalf of teachers, often positioning the teacher as a passive end-user of a finished technological product. This conceptual paper argues that such a framing undervalues the professional judgement, contextual knowledge, and pedagogical creativity that teachers bring to AI-integrated learning environments, and proposes an alternative paradigm: augmentation achieved through co-design. Drawing on a synthesis of recent empirical and theoretical literature on teacher–AI collaboration, technological pedagogical content knowledge, and human-AI complementarity, the paper distinguishes automation from augmentation and traces the evolution of teacher roles along a continuum from passive recipient, to assistant-user, to augmented practitioner, to genuine co-design partner. It proposes a four-dimensional Teacher-AI Co-Design Framework built around efficiency, responsiveness, creativity, and equity affordances, through which teachers actively shape, question, and refine AI outputs rather than merely adopting them. The paper further examines the implications of this repositioning for teacher professional development, curriculum design, and educational policy, with particular attention to the infrastructural, epistemic, and equity-related challenges confronting teachers in the Global South, including Nigeria. It concludes that repositioning teachers as co-designers, rather than passive operators, is essential if AI-integrated learning ecosystems are to remain pedagogically sound, ethically grounded, and contextually responsive, and it offers recommendations for teacher education curricula, institutional policy, and participatory AI tool design, alongside a call for further empirical research on co-design practice in under-represented, resource-constrained educational settings.

Keywords: Artificial Intelligence, Teacher Agency, Co-Design, Augmentation, Instructional Design, Educational Technology

Introduction

Artificial intelligence (AI) has moved from the margins of educational technology discourse to its center. Adaptive tutoring systems, generative content tools, automated assessment engines, and learning analytics dashboards are now marketed directly to schools, universities, and individual teachers, promising efficiency, personalization, and scale. Much of this discourse, however, has been organized around a narrative of automation: the substitution of tasks that teachers have traditionally performed – explaining, questioning, grading, sequencing, and diagnosing – with software that performs the same functions faster and, it is claimed, more consistently (Fadel, Holmes, & Bialik, 2019). Within this narrative, the teacher is frequently cast as a passive recipient or, at best, a supervised operator of a finished technological product designed elsewhere by engineers and instructional technologists who may never have taught a class.

This paper takes as its starting point the theme of the Association for Innovative Technology Integration in Education (AITIE) conference, which calls for a reimagining of teaching and learning ecosystems as they move from automation to augmentation in the AI era. It argues that this reimagining cannot occur through technical innovation alone; it requires a deliberate repositioning of the teacher's role in the design, not merely the delivery, of AI-integrated instruction. Where automation treats the teacher as a consumer of AI outputs, augmentation, understood properly, treats the teacher as a co-producer of those outputs – a professional whose pedagogical judgement, contextual knowledge of learners, and disciplinary expertise are indispensable inputs into how AI systems are configured, prompted, interpreted, and applied in the classroom.

The paper is organized in six further parts. It first clarifies the conceptual distinction between automation and augmentation as applied to educational AI. It then outlines a theoretical framework that draws on technological pedagogical content knowledge and human-AI complementarity research. A review of recent literature follows, tracing the shift from automation-oriented deployments of AI toward emerging models of teacher–AI co-design, including relevant global policy developments. The paper then proposes a conceptual model – the Teacher-AI Co-Design Continuum – before discussing implications for practice, the barriers that must be addressed, particularly in resource-constrained contexts such as Nigeria, and recommendations for teacher education, institutional policy, and AI tool design.

Conceptual Clarification: From Automation to Augmentation

Automation, in the context of educational AI, refers to the delegation of previously teacher-performed tasks to a computational system that executes them with minimal ongoing human input once configured. Automated grading engines, adaptive practice platforms that sequence content algorithmically, and chatbot tutors that respond to student queries independently of teacher oversight are illustrative examples. Automation is not inherently harmful; it can relieve teachers of repetitive administrative burdens and extend instructional reach. The concern raised in the literature is that when automation becomes the dominant framing of AI in education, teachers risk being repositioned as implementers of externally designed systems rather than as designers of learning experiences, a shift that can erode instructional expertise and professional agency over time (Fadel et al., 2019).

Augmentation, by contrast, describes technology that extends and amplifies human capability rather than replacing it. Luckin, Holmes, Griffiths, and Forcier (2016) argued that AI in education should be conceived as a means of unleashing intelligence – both the learner's and the teacher's – rather than substituting for it, positioning AI as an instrument that makes visible aspects of learning and teaching that were previously difficult to observe, such as misconceptions, engagement patterns, or the pacing needs of individual students. Augmentation, on this reading, is not a property of the technology alone but of the relationship established between the technology and the professional who uses it. That relationship is most fully realized through co-design: the deliberate, iterative, and reciprocal process by which teachers and AI systems, together with the researchers, developers, and institutions that shape them, jointly determine what a learning task, resource, or intervention will look like (Sanders & Stappers, 2008). Co-design does not require teachers to become programmers; it requires that their pedagogical expertise function as a design input rather than an afterthought.

Theoretical Framework

This paper draws on three complementary theoretical strands. The first is technological pedagogical content knowledge (TPACK), which conceptualizes effective technology integration as arising from the dynamic interaction of technological, pedagogical, and content knowledge rather than from technical proficiency alone (Mishra & Koehler, 2006). TPACK implies that teachers cannot be effectively AI-augmented if AI tools are treated as content-neutral utilities to be dropped into existing lesson plans; the tools themselves must be shaped, or at least selected and adapted, in light of what is being taught, to whom, and how.

The second strand is the concept of human-AI complementarity, which holds that the most effective classroom systems are those in which AI performs the functions it is comparatively better

at, such as processing large volumes of performance data in real time, while teachers retain functions requiring situated judgement, empathy, and ethical discernment (Holstein, McLaren, & Aleven, 2019). Complementarity reframes the design question away from "what can AI do instead of the teacher" toward "what combination of AI and teacher action produces the best outcome for this learner, in this context, at this moment."

The third strand is the emerging notion of hybrid or distributed intelligence in instructional design, which treats the design of learning tasks as a jointly constructed artifact rather than a product generated by either the teacher or the AI system in isolation (Frøsig & Romero, 2024). Taken together, these three strands support the paper's central claim: that meaningful augmentation in AI-integrated learning environments depends on structures, competencies, and institutional conditions that allow teachers to function as co-designers rather than end-users.

Literature Review

The Automation Paradigm and Its Limits

A substantial body of early AI-in-education literature focused on what AI systems could do independently of teachers: diagnosing misconceptions, generating personalized practice sequences, and providing instant feedback (Fadel et al., 2019). Critics of this orientation have argued that an excessive focus on automation risks reducing teaching to a set of measurable, delegable tasks, and that it marginalizes the relational and improvisational dimensions of classroom practice that are not easily captured by algorithms (Selwyn, 2019). Empirically, this concern has been borne out in reviews of AI applications in higher education, which found that educators were largely absent from the design and evaluation of the AI systems intended for their own classrooms, with technical and computer science perspectives dominating the literature at the expense of pedagogical ones (Zawacki-Richter, Marín, Bond, & Gouverneur, 2019). This absence is significant: when the professionals who must ultimately use a system in a live classroom are excluded from its design, the resulting tools are more likely to misalign with curricular goals, classroom realities, and learner diversity.

Emerging Models of Teacher–AI Co-Design

A more recent and rapidly growing strand of research has sought to correct this imbalance by actively involving teachers in the design of AI-integrated curricula and tools. Lin and Van Brummelen (2021) organized co-design workshops with fifteen K-12 teachers to embed AI concepts into core subjects such as English language arts, social studies, and literacy instruction, finding that teachers required structured scaffolding around AI ethics and data literacy but were able to generate rich, subject-integrated curricular ideas when given the opportunity to shape the design process rather than simply receive a finished product. Similarly, Zhang et al. (2023) demonstrated that middle school AI curricula grounded in ethical reasoning and career relevance, co-developed with classroom teachers, supported more meaningful AI literacy outcomes than curricula designed without direct teacher input. Krushinskaia, Elen, and Raes (2023) went further, developing a co-instructional-designer chatbot intended not to generate finished lessons for teachers but to support them as a dialogic partner throughout the design process itself.

A recent systematic review of twenty-eight empirical studies on teacher–AI collaboration in learning task design offers the most comprehensive account to date of how this collaboration is actually practiced (Wang, Mingzhuo, & Islam, 2026). The review found that the most common

mode of collaboration, accounting for roughly a third of the studies examined, positioned AI as an assistant or draft generator whose output teachers subsequently reviewed and refined, with teachers acting as the primary instructional architects. More integrative modes, in which AI functioned as a genuine co-designer or dialogic partner engaged in iterative ideation with the teacher, were considerably less common, appearing in only a small subset of the studies reviewed, despite offering, in the review's assessment, the richest pedagogical potential. The review also identified four recurring affordances through which AI tools shape teacher design work: efficiency, in reducing the time and cognitive load associated with lesson preparation; responsiveness, in supporting real-time adjustments to instruction based on learner data; creativity, in stimulating idea generation and challenging teachers' initial assumptions; and equity, in enabling differentiated, culturally responsive task design for diverse learners (Wang et al., 2026). These four affordances provide a useful empirical foundation for the conceptual model proposed later in this paper.

Policy Momentum: The UNESCO AI Competency Framework for Teachers

International policy has begun to formalize the expectation that teachers should be active, competent participants in AI-integrated education rather than passive recipients of automated tools. The AI Competency Framework for Teachers, released by UNESCO in 2024, defines fifteen competency blocks organized across three progression levels and five aspects, including pedagogical application and professional engagement, and is explicitly grounded in a human-centered approach that safeguards teacher agency and accountability rather than displacing it (Miao & Cukurova, 2024). The framework's emphasis on protecting teachers' rights and enhancing human agency lends institutional legitimacy to the co-design orientation advocated in this paper, situating it not as an idealistic aspiration but as an emerging global policy expectation.

The Nigerian and Global South Context

Much of the empirical literature on teacher–AI co-design reviewed above originates from well-resourced educational systems in North America, Europe, and East Asia, where reliable connectivity, institutional AI licensing, and dedicated professional development time are comparatively available. Nigerian and other Global South educational contexts present a distinct set of structural conditions: inconsistent electricity supply, uneven internet access across urban and rural institutions, large class sizes, limited institutional budgets for licensed AI tools, and teacher professional development systems that are often under-resourced relative to the pace of technological change. These conditions do not diminish the case for repositioning teachers as co-designers; if anything, they strengthen it. Where infrastructural and financial constraints limit which AI tools can even be deployed, teacher judgement about which affordances are genuinely useful, which tools are contextually appropriate, and how scarce access should be allocated becomes an even more decisive design input than in better-resourced systems. A co-design orientation that is imported wholesale from high-resource contexts without adaptation to these realities risks reproducing the very automation-first, teacher-excluded pattern this paper cautions against, only now imposed by external vendors rather than domestic policy.

Repositioning Teachers as Co-Designers: A Conceptual Model

Synthesizing the theoretical and empirical strands reviewed above, this paper proposes the Teacher-AI Co-Design Continuum, a conceptual model that situates teacher roles along four progressive positions rather than treating "automation" and "augmentation" as a simple binary.

The first position, substitution, describes contexts in which AI performs a task entirely independently of teacher input, with the teacher functioning largely as an observer or auditor of system outputs after the fact. The second position, assisted practice, describes the most common pattern identified in current research, in which AI generates drafts, suggestions, or content that the teacher subsequently edits and contextualizes, retaining authorship but not shaping the underlying generative process (Wang et al., 2026). The third position, augmented practice, describes a closer integration in which the teacher actively directs AI outputs through deliberate prompting, configuration, and interpretation, using the system as an extension of their own instructional reasoning rather than a separate source of content. The fourth and most advanced position, co-design partnership, describes an iterative, dialogic relationship in which the teacher and the AI system jointly shape a learning task through successive rounds of generation, critique, and revision, with the teacher retaining final pedagogical and ethical authority throughout (Krushinskaia et al., 2023).

Movement along this continuum toward co-design partnership is, in this paper's framing, mediated by four affordances that AI tools can offer when appropriately configured and when teachers are equipped to engage with them critically: efficiency affordances that free teacher time and cognitive capacity for higher-order design work; responsiveness affordances that allow real-time adaptation to learner performance and need; creativity affordances that stimulate divergent pedagogical thinking and challenge default assumptions; and equity affordances that support differentiated, inclusive task design for learners with diverse needs, languages, and abilities (Wang et al., 2026). These affordances do not operate independently; efficiency gains, for instance, can create the time needed for teachers to pursue more creative or equity-oriented design work, while creativity affordances can, in turn, generate more equitable and differentiated task variations. The model therefore treats augmentation not as an inherent property of a given AI tool but as an achievement that depends on how teacher agency, institutional support, and tool design interact.

Implications for Practice

Teacher Professional Development

If teachers are to function as co-designers rather than end-users, professional development must move beyond basic digital literacy or one-off tool-training workshops toward sustained engagement with prompt literacy, critical evaluation of AI-generated content, and design thinking (Rosenbaum et al., 2023, as cited in Wang et al., 2026). Prompt literacy in particular has emerged as a foundational, though frequently overlooked, professional competency: teachers who lack the skill to craft precise, pedagogically meaningful prompts are more likely to receive generic or shallow AI outputs, which in turn reinforces an assistant-level rather than co-design-level relationship with the technology (Wang et al., 2026). Professional development structured around communities of practice, in which teachers iteratively experiment with AI-supported design tasks and share emerging strategies, is likely to be more effective than centralized, one-time training sessions, particularly in contexts such as Nigeria where formal continuing professional development infrastructure is uneven across institutions.

Curriculum and Instructional Design

Teacher education curricula, at both pre-service and in-service levels, should extend TPACK-based instructional design training to explicitly address AI-mediated task design, treating the negotiation between teacher judgement and AI suggestion as a skill to be taught rather than assumed. This

includes training pre-service teachers to critically interrogate AI-generated lesson materials for curricular alignment, cultural appropriateness, and factual reliability before adoption, rather than treating AI output as a finished product.

Institutional Policy and Governance

At the institutional and system level, policies governing AI adoption in schools and universities should be explicitly aligned with human-centered frameworks such as UNESCO's AI Competency Framework for Teachers, ensuring that procurement decisions, professional development investment, and classroom AI governance protect and strengthen teacher agency rather than treating teachers as passive implementers of vendor-designed systems (Miao & Cukurova, 2024). For Nigerian tertiary and secondary institutions in particular, this implies building institutional AI policy around participatory processes that include practicing teachers and lecturers from the outset, rather than adopting externally designed AI governance frameworks without local adaptation.

Challenges and Barriers

Repositioning teachers as co-designers faces several documented barriers. First, prompt literacy and AI output quality remain uneven; teachers, particularly those newer to AI-supported design, often lack the skill to elicit pedagogically meaningful outputs, leading to shallow or generic content that reinforces rather than challenges an assistant-level relationship with AI (Wang et al., 2026). Second, alignment and contextual sensitivity are frequently cited concerns, as AI-generated materials often fail to reflect specific curricular goals, classroom realities, or learner needs, requiring active teacher intervention to be usable. Third, epistemic uncertainty and limited explainability undermine teacher trust; when teachers cannot understand how an AI system arrived at a given recommendation, their capacity to exercise informed pedagogical judgement over that recommendation is correspondingly weakened (Wang et al., 2026). Fourth, institutional and infrastructural constraints, including unstable connectivity, information overload from complex analytics dashboards, and limited technical support, have been shown to undermine the sustainability of even well-designed teacher–AI collaboration tools over time (Holstein et al., 2019). In resource-constrained contexts such as Nigeria, these infrastructural barriers are compounded by limited institutional funding for licensed AI tools, large class sizes that reduce the time available for iterative design work, and continuing professional development systems that have not yet been systematically redesigned around AI-era competencies. Finally, curricular rigidity and limited teacher autonomy within some education systems can constrain the experimentation that co-design requires, particularly at the secondary and primary levels, which remain comparatively underrepresented in the empirical literature relative to higher education and teacher training contexts (Wang et al., 2026).

Recommendations

Based on the foregoing analysis, this paper offers five recommendations. First, teacher education institutions, including faculties of education such as the University of Lagos, should embed AI co-design competencies, including prompt literacy, critical evaluation of AI output, and participatory design thinking, into both pre-service curricula and in-service professional development programmes. Second, schools and universities should establish co-design labs or communities of practice in which teachers collaboratively experiment with, critique, and refine AI-supported instructional materials, rather than relying solely on vendor training. Third, national and institutional AI-in-education policies should be explicitly aligned with human-centered

international frameworks, such as the UNESCO AI Competency Framework for Teachers, to ensure that teacher agency is protected as AI adoption accelerates. Fourth, developers of educational AI tools should adopt participatory design processes that involve practicing teachers, particularly from under-represented and resource-constrained contexts, from the earliest stages of tool development, with explainability and contextual adaptability treated as core design requirements rather than optional features. Fifth, further empirical research is needed on teacher–AI co-design practice in Global South contexts specifically, including Nigeria, where infrastructural and institutional conditions differ substantially from the well-resourced settings that currently dominate the literature.

Conclusion

The theme guiding this conference, the movement from automation to augmentation in the reimagining of teaching and learning ecosystems, cannot be achieved through technological innovation alone. It requires a deliberate repositioning of teachers from passive recipients and supervised operators of AI systems to active co-designers of AI-integrated instruction. This paper has argued that such a repositioning is both conceptually coherent, grounded in established frameworks of technological pedagogical content knowledge and human-AI complementarity, and increasingly supported by empirical evidence and international policy. The proposed Teacher-AI Co-Design Continuum offers a way of understanding this repositioning as a gradual, affordance-mediated process rather than a single technological shift, while attention to the distinct infrastructural and institutional realities of contexts such as Nigeria underscores that this repositioning must be pursued differently, and perhaps more urgently, outside the well-resourced settings where most current research has taken place. Ultimately, AI-integrated learning environments will be pedagogically sound, ethically grounded, and contextually responsive only to the extent that the teachers who inhabit them are recognized, resourced, and trained not merely as users of AI, but as its co-designers.

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APPLICATIONS OF ARTIFICIAL INTELLIGENCE (AI) FOR SKILL ACQUISITION IN TECHNOLOGY EDUCATION INSTITUTIONS IN NIGERIA

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Abstract

In Nigeria, where technology education is playing a critical role in addressing unemployment, industrial growth, and economic development, the applications of AI offer significant opportunities for improving skill acquisition .Artificial Intelligence (AI) has emerged as one of the most transformative technologies of the twenty-first century, revolutionizing education through intelligent systems that enhance teaching, learning, and assessment. Technology education institutions equip learners with practical skills, technical competencies, and innovative capabilities needed for national development. However, challenges such as inadequate laboratory facilities, obsolete equipment, shortage of qualified teachers, and limited access to modern learning resources hinder effective skill acquisition in most technology education institutions in Nigeria. AI presents significant opportunities to address these challenges through personalized learning, virtual laboratories, intelligent tutoring systems, adaptive learning environments, automated assessment, AI-powered content creation, and predictive learning analytics. This paper examines the applications of AI in promoting skill acquisition in technology education institutions in Nigeria, discusses its benefits, identifies implementation challenges, and provides recommendations for effective integration.

Keywords: Artificial Intelligence; Technology education, Skill acquisition, Applications of AI

Introduction

Technology education aims to equip learners with practical skills, technical competencies, and innovative capabilities needed for modern industries and national development. Technology education .focuses on developing practical and technological skills required for industrial and economic development. It is a field of study that prepares learners with scientific, technical, vocational, and entrepreneurial skills necessary for solving practical problems in society. It combines theoretical instruction with practical experiences to develop competent graduates capable of functioning effectively in modern industries (Federal Republic of Nigeria, (FRN) 2013).

In Nigeria, Technology education is a post-secondary programme which is obtainable at the polytechnics, Monotechnics, Colleges of Technology, Colleges of Education (Technical), and Universities (FRN, 2013). These institutions train technicians/technologists and technology education teachers. Technology education was formerly restricted to technical education, which in essence meant skill training in crafts and in certain trades such as building, automechanics and

woodwork. In fact, the two terms 'Technology Education' and 'Technical Education' were and still are, often used interchangeably. However, the major fabric of technology education involves education in the process of applying both science and technical education to practical problem solving. This means that technology education involves more than skill training or technical education. Technology education is essential for developing skilled manpower capable of supporting national development. Hence, acquisition of practical skill, technologies and related sciences for work is highly essential in technology education.

Skill acquisition refers to the systematic process through which individuals learn, develop, and master practical competencies necessary for performing specific occupational tasks effectively. It involves continuous learning through practice, feedback, experimentation, and application of knowledge in real-life situations (United Nations Educational Scientific and Cultural Organization (UNESCO), 2021). Technology education emphasizes skill acquisition in areas such as: Electrical/Electronic, mechanical technology, building/woodwork technology, and other related field. In Nigeria, where technology education is expected to produce skilled manpower capable of meeting industrial demands, Artificial Intelligence (AI) presents enormous opportunities for improving students' practical competencies and employability. Today, AI has become one of the most transformative technologies of the twenty-first century, revolutionizing education and other fields of human endeavors, traditional approaches to teaching and learning in technology education alone is not sufficient to meet the demands of Industry 4.0, where digital skills, automation, and advanced technologies are becoming increasingly important. The world of work in the present time according to Hassan et al, (2021) demands the highest level of technological skills with extensive practical expertise because industries now lean toward knowledge-based economics while undergoing digital transformation. The integration of AI applications into Technology education will provide new methods for teaching, assessment and practical skill development.

The Need for Application of Artificial Intelligence in Technology Education

Artificial Intelligence refers to the ability of computer systems to perform tasks that normally require human intelligence, including learning, reasoning, decision-making, speech recognition, image processing, and language translation (Russell & Norvig, 2021). According to Rainer et al., (2016) AI is designed to create intelligent systems with computer programs or machines which are capable of intelligent behaviours including learning, reasoning, problem- solving, perception, and creating. AI is called 'machine intelligence'. It is an aspect of computer science where machines are programmed with the ability to perform intelligent tasks that are usually undertaken by humans (Ali, et al. 2024; Dwivedil et al. 2023). AI is therefore a universal field that is relevant to all intellectual tasks. Educational activities around the world have been significantly exposed to technological advancements in recent times by the intervention of recent development in Artificial Intelligence. AI is transforming industries and requiring a future-ready workforce. Technology education students are at the forefront, prepared to inherit this evolving digital world through technology.

Technology education in Nigeria is facing challenges such as inadequate laboratory facilities, obsolete equipment, shortage of qualified teachers, and limited access to modern learning resources which are hindering effective skill acquisition in most of the technology education institutions. AI presents significant opportunities to address these challenges through personalized

learning, virtual laboratories, intelligent tutoring systems, adaptive learning environments, automated assessment, AI-powered content creation, and predictive learning analytics.

Applications of AI for Skill Acquisition in Technology Education

Artificial Intelligence (AI) applications are believed to enhance teaching and learning for effective achievement of higher educational goals. So, many of the applications of AI such as; personalized learning, virtual laboratories, intelligent tutoring systems, adaptive learning environments, automated assessment, AI-powered content creation, and predictive learning analytics are currently being used to support skill acquisition in sciences and technology disciplines to make learning process more practical and effective.

Personalized Learning

Personalized learning refers to educational activities that cater to individual student needs through tailoring educational experiences to accommodate individual students' unique needs, learning styles, and pace. It is a means by which content of instruction is delivered based on each student's ability, weaknesses, learning difficulties, and learning styles allowing students to learn concepts at their own pace (Mufdalifah, 2017). Artificial Intelligence (AI) has provided a means for personalizing the learning experience, bringing about a paradigm shift in the conventional concept of personalized learning. According to Jian (2023) the influx of massive online courses, digital classrooms, and e-learning platforms, educational institutions and technologists have realized the challenges of a "one-size-fits-all" approach, leading to the exploration of AI's potential in enhancing personalization.

Personalized learning has become an important approach in technology education because it helps students acquire technical skills more effectively by providing individualized learning experiences. Teachers can use AI personalized learning application to assess individual learners' strengths and weaknesses and provide customized learning pathways and in such a way students in technology education programmes can receive training materials that match their learning speed and skill level, improving understanding and competence. Besides, AI provides competency-based Education through individualized learning path which enables students to advance only after demonstrating mastery of specific technological skills rather than spending a fixed amount of time on a lesson. This ensures strong practical competence before moving to advanced concepts. It also offers personalized feedback and assessment in which digital tools provide immediate feedback on assignments, coding exercises, simulations, and practical tasks with teachers serving as guidance for students based on individual strengths and weaknesses.

Intelligent Tutoring Systems (ITS)

Intelligent Tutoring Systems (ITS) are AI-driven educational software applications that provide personalized instruction and feedback to learners. Unlike traditional computer-assisted learning, ITS supports skill acquisition by adjusting lessons and exercises based on the learner's strengths and weaknesses, providing immediate feedback though identification of errors instantly and provides explanations to help learner correct mistakes. ITS offers opportunity for adaptive assessment by continuously evaluating learner's performance and modifies instruction accordingly. It also offers skill tracking to monitors students' progress and identifies areas

requiring further practice. AI-powered intelligent tutoring systems in technology education provide simulations for students to learn task performance in virtual environments, such as machine operation. Teachers can also use ITS where students struggle to accomplish tasks for providing scaffolding such as step-by-step guidance, hints, or explanations to help students complete the task, gradually withdrawing support as the student gains proficiency. In doing so, ITS tracks a student's progress, identifying mastered skills and concepts, as well as areas needing more practice. The ITS then selects appropriate practice problems or tasks to reinforce learning and build confidence (Wang et al. 2003; Fitria, 2021).

Virtual Reality Laboratories and Simulations

Virtual reality is a computer technology that enables students to explore and manipulate computer-generated, 3D objects in a multimedia environments in real time. It enhances online testing, spatial visualization, students' engagement, spatial perception, and comprehension of complex abstract concepts (Mojica-Irigoyen et al, 2023). Virtual reality is an interactive computer technology that creates a completely convincing illusion of being immersed in an artificial world which exists only inside a computer. Virtual reality is a superior environment for spatial skills enhancement which is essential for Technical graphics and engineering graphics. AI powered virtual reality creates immersive environments for training in automotive repair, welding, and machining for technology education students. According to Halabi (2020) the design of virtual laboratories related to electrical circuits helps students gain virtual access to laboratories and collaborate remotely whilst performing experiments. AI provides a virtual reality environment through adaptive learning environments, which allows the development of practical sessions and exercises without the limitations of physical resources. AI-powered simulations create safe, cost-effective environments for hands-on practice. For instance. Technology education students and teachers can experiment with electrical circuits, CAD/CAM designs, or programming robots without physical components. Teachers can also use a combination of virtual reality and simulation technologies to allow students to practice technical skills in safe environments. For example, students can simulate machine operations,

AI-Powered Adaptive Learning Systems

AI-powered adaptive learning systems personalize instruction by analyzing a learner's knowledge, pace, preferences, and performance in real time. In technology education, these systems help learners acquire technical skills more efficiently by adjusting content, difficulty, feedback, and learning pathways to meet individual needs. According to Pane et al, (2015). Teachers can use Adaptive platforms to accelerate mastery learning and reduce time-to-completion.

Automated Assessment and Feedback

AI-automated assessment and grading uses artificial intelligence to automatically score and evaluate student work, offering efficient, consistent, and immediate feedback, saving teacher's time and reducing workload. Automated assessment and feedback are increasingly used in technology education to improve skill acquisition by providing timely, objective, and personalized evaluation of learners' performance. The use of AI automated assessment makes it easier for teachers to prepare programming and coding assessment which aevaluates students' code for correctness, efficiency, and style and provides instant feedback on syntax errors, logic errors, and code optimization to supports practice through repeated attempts without requiring constant instructor intervention. In essence, teacher no longer needs to make corrections on students work

manually (Fitria, 2021). AI automated assessment and feedback supports practice through repeated attempts without requiring constant teacher's intervention. AI automated assessment also provides simulation-based skills assessment which is used for assessing students' performance in virtual laboratories and practical simulations. This is commonly used in electronics, robotics, networking, and other technology education fields.

AI-Powered Content Creation

AI-powered content authoring tools help educators generate quizzes, simulations, and adaptive exercises tailored to learner profiles (Chen, Xie, & Hwang, 2020). Artificial intelligence is transforming technology education by enabling teacher and students create personalized, engaging, and accessible learning contents. AI-powered content creation uses machine learning, natural language processing, and generative AI to produce educational materials such as lesson notes, quizzes, coding exercises, simulations, videos, and interactive tutorials for practical activities. This approach helps learners acquire practical technology skills more efficiently while supporting teachers in delivering high-quality instruction.

Predictive Analytics and Learning Analytics

Technology education aims at equipping learners with practical and theoretical skills needed for modern industries. As institutions increasingly adopt digital learning platforms, large volumes of learner data are generated. These are two important data-driven approaches: learning analytics and predictive analytic which help teachers understand how students learn, identify learning challenges, and improve skill acquisition. Learning analytics refers to the process of collecting, measuring, analyzing, and reporting data about learners and their learning environments to improve teaching and learning outcomes. In technology education, learning analytics can be used to: Monitor student engagement in online learning platforms. Track attendance, assignment completion, and practical laboratory performance and provide personalized learning experiences based on individual progress.

Challenges of AI Adoption in Technology Education Institutions

Despite the benefits and potentials of AI applications, several challenges may hinder the effective use of AI in Nigerian Technology education institution. These includes:

1. Poor digital infrastructure such as lack of reliable internet access, electricity supply, and modern digital equipment required for AI applications.
2. Limited funding for development and maintenance of hardware and software AI-based educational systems.
3. Lack of technical skills among teachers and instructors to effectively use AI tools in teaching and training.
4. Data privacy and ethical concerns: AI systems depend on learner data, proper policies are needed to protect privacy, ensure fairness, and prevent misuse of information.
5. Resistance to technological change: Some educators and institutions may be reluctant to adopt AI due to unfamiliarity, fear of replacement, or lack of confidence in new technologies.

Conclusion

Artificial intelligence has the potential to transform technology education in Nigeria by improving skill training, increase access to learning and preparing graduates for the challenging demands of the workforce. Although, challenges such as infrastructure limitations, funding constraints, and skill shortages exist, strategic investment and collaboration can enable Nigeria to harness AI for effective technology education. The future of skill development depends on combining human expertise with intelligent technologies to produce innovative competent and employable skilled graduates in the technology education institutions.

Recommendations

To successfully integrate Ai into technology education in Nigeria, the following measures are recommended:

1. Government and Technology Education Institutions administrators should invest in digital infrastructure.
2. In-service training on AI Applications and Digital Teaching Methods should be continuously organized for technology education teachers.
3. School-industry partnership should be developed between government, industry, technology companies and technology institutions.
4. AI-related courses and digital literacy should be included into technology education programmes curricula
5. Policies should be developed to address ethical issues, data protection, and responsible use of AI
6. Technology education institutions should adopt affordable AI solutions that fit local needs and available resources.

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FROM AUTOMATION TO AUGMENTATION: A HUMAN-AI AUGMENTATION LADDER FOR CO-CREATING EDUCATIONAL MEDIA IN THE AI-ERA TEACHING AND LEARNING ECOSYSTEM

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Abstract

Discourse on artificial intelligence (AI) in education has, for much of the past decade, been framed largely in the language of automation: intelligent tutoring systems that automate feedback, algorithms that automate assessment scoring, and recommendation engines that automate content sequencing. This automation framing, while productive, has tended to cast the human educator as a supervisor of machine output rather than as an active creative partner, and it has been particularly limiting in the domain of educational media production, where instructional videos, e-learning modules, and broadcast-style audio lessons are still frequently designed as if AI were merely a faster typist or a cheaper voice-over artist. This paper responds directly to the AITIE conference theme of moving 'from automation to augmentation' by proposing a Human-AI Augmentation Ladder for the co-creation of educational media, a conceptual model that distinguishes four progressively deeper modes of human-AI collaboration: automated substitution, augmented assistance, collaborative co-creation, and redefined ecosystems. The model draws on Licklider's (1960) early theorisation of man-computer symbiosis, Engelbart's (1962) framework for augmenting human intellect, and Puentedura's SAMR model of educational technology integration, extending these augmentation-oriented traditions into the specific practice of educational media production. The paper further draws on the author's dual grounding in broadcast media practice and educational technology research to argue that broadcasting has historically modelled augmentation rather than automation, with human editorial judgement persisting alongside successive waves of production technology. The paper discusses how the Augmentation Ladder can guide curriculum design, faculty development, and institutional policy in Nigerian higher education and Technical and Vocational Education and Training (TVET) as institutions reimagine their teaching and learning ecosystems for the AI era, and it closes with ethical considerations and recommendations for empirical validation of the proposed ladder.

Keywords: automation, augmentation, human-AI co-creation, educational media, SAMR, generative artificial intelligence, broadcast media, teaching and learning ecosystems

Introduction

The AITIE conference theme, 'From Automation to Augmentation: Reimagining Teaching and Learning Ecosystems in the AI Era,' names a distinction that has quietly organised much of the debate about artificial intelligence in education without always being made explicit. Automation, in this context, refers to the use of AI to perform a task that a human would otherwise perform, with the goal of replacing human effort at that task. Augmentation, by contrast, refers to the use of AI to extend, amplify, or enrich human capability, with the human remaining an active, indispensable participant in the outcome (Licklider, 1960; Engelbart, 1962). The distinction

matters enormously for educational media creation. An automation-first approach treats generative AI as a replacement for the scriptwriter, narrator, or video editor; an augmentation-first approach treats it as a collaborator that expands what a single educator or small production team can create, without displacing human pedagogical and creative authority.

This paper argues that educational media creation is a domain in which the augmentation framing is not merely preferable but necessary, because the artefacts produced, videos, audio lessons, animations, interactive modules, are pedagogical instruments whose effectiveness depends on human judgement about learners, culture, and curriculum that current AI systems cannot supply on their own (Holmes, Bialik, & Fadel, 2019; Selwyn, 2019). Writing from the standpoint of a practitioner-researcher active in both broadcast media production and educational technology, the author draws on broadcasting's long history of absorbing successive production technologies without ceding editorial authority to argue that this history offers a template for what augmentation-oriented human-AI co-creation in educational media can look like.

Statement of the Problem

Much existing scholarship on AI in education continues to foreground automation-oriented use cases, automated grading, automated tutoring, automated content recommendation — even as the AITIE conference theme signals a field-wide call to reorient discourse toward augmentation (Zawacki-Richter, Marín, Bond, & Gouverneur, 2019). In the specific domain of educational media production, there is limited conceptual work distinguishing degrees of human-AI collaboration or offering practitioners a graduated model for moving deliberately from automation toward genuine augmentation and co-creation. Nigerian tertiary institutions, in particular, currently lack a locally grounded framework to guide this transition, leaving educators to adopt generative AI tools for media production in an ad hoc manner, often defaulting to automation-style use (having AI generate a finished script or narration wholesale) rather than a more augmentation-oriented, iterative collaboration.

Purpose and Objectives

This paper proposes and theoretically grounds a Human-AI Augmentation Ladder for educational media co-creation, aligned with the AITIE conference's automation-to-augmentation theme. Specifically, it seeks to:

1. Trace the conceptual distinction between automation and augmentation as it applies to AI use in educational media production;
2. Propose a four-rung ladder model describing progressively deeper forms of human-AI collaboration in media co-creation;
3. Illustrate the ladder using analogies from broadcast media production practice; and
4. Discuss implications for reimagining teaching and learning ecosystems in Nigerian higher education and TVET in the AI era.

Literature Review

From Automation to Augmentation: A Conceptual Lineage

The augmentation framing of human-computer interaction predates contemporary generative AI by more than six decades. Licklider (1960) proposed the concept of man-computer symbiosis, envisioning computers not as replacements for human cognition but as partners that would extend human capability in tasks requiring judgement. Engelbart (1962) extended this vision into a formal framework for augmenting human intellect, arguing that technology's highest value lies in enhancing, rather than substituting for, human problem-solving capacity. These foundational ideas anticipate, in striking terms, the contemporary debate about whether generative AI in education should be pursued as an automation technology or an augmentation technology.

SAMR and Augmentation in Educational Technology

Within educational technology specifically, Puentedura's SAMR model (Substitution, Augmentation, Modification, Redefinition) has long offered a graduated way of thinking about how digital tools reshape teaching tasks, moving from simple substitution of an analogue tool through to redefinition of tasks that were previously inconceivable (Puentedura, 2006). Although SAMR was developed prior to the generative AI era, its logic of graduated technology integration is directly applicable to human-AI co-creation of educational media, and it forms a key conceptual ancestor of the ladder proposed in this paper.

Generative AI in Educational Media Production

Generative AI tools now support scriptwriting, text-to-speech narration, AI-generated imagery and avatar presenters, and automated rough-cut video and audio editing. Kasneci et al. (2023) note that such tools present genuine opportunities for expanding what educators can produce, while cautioning that unsupervised use risks factual inaccuracy and bias. Holmes et al. (2019) similarly argue that AI's educational value depends heavily on how it is integrated into human decision-making processes rather than on the sophistication of the technology alone.

Broadcasting as a Historical Model of Augmentation

Broadcast media production offers a instructive historical case of augmentation rather than automation. Successive waves of production technology, from analogue tape editing to digital audio workstations, studio automation systems, and now AI-assisted transcription and editing, have repeatedly expanded what broadcast producers and editors could accomplish, without displacing the human editorial function of deciding what airs and how it is framed for an audience (Bates, 2019). This paper treats that persistence of human editorial authority through waves of technological change as an existence proof that augmentation, rather than automation, is achievable in a live production environment, and as a template for educational media co-creation.

Theoretical Framework

The Augmentation Ladder proposed in this paper is grounded theoretically in Licklider's (1960) man-computer symbiosis and Engelbart's (1962) augmentation framework, operationalised for educational technology through the graduated logic of Puentedura's (2006) SAMR model. It is

further informed by activity theory (Engeström, 1987), which frames educational media production as a structured activity system with human subjects, AI-mediated tools, and a socially defined division of labour, and by the Technological Pedagogical Content Knowledge (TPACK) framework (Mishra & Koehler, 2006), extended here to include the educator's capacity to direct and calibrate AI collaboration at increasing levels of depth.

The Human-AI Augmentation Ladder for Educational Media Co-Creation

Table 1 presents the proposed four-rung ladder, moving from automated substitution, which reproduces the automation logic the AITIE theme calls on the field to move beyond, through augmented assistance and collaborative co-creation, to redefined ecosystems, in which AI enables instructional media forms that were not previously feasible at all. Movement up the ladder is not assumed to be strictly linear or universally desirable for every task; rather, the ladder offers educators a vocabulary for naming where a given AI-assisted production practice currently sits and for making deliberate choices about whether and how to move toward deeper augmentation.

Table 1*; *The Human-AI Augmentation Ladder for Educational Media Co-Creation

Rung	Orientation	Description in Educational Media Creation
1. Automated Substitution	Automation	AI performs a mechanical task a human would otherwise do manually, with no change to the underlying process (e.g., auto-captioning, auto-transcription of a recorded lecture).
2. Augmented Assistance	Augmentation	AI drafts or generates a first-pass artefact (narration script, illustrative image, rough voice-over) that a human editor substantially reviews and reshapes before use.
3. Collaborative Co-Creation	Augmentation	Human and AI iterate together across several cycles, each refining the other's contribution, similar to a producer-scriptwriter dialogue in a newsroom.
4. Redefined Ecosystems	Augmentation	AI enables instructional media formats not previously feasible — e.g., dynamically personalised broadcast-style lessons generated per learner profile — reshaping the teaching-learning ecosystem itself.

Rung 1: Automated Substitution

At the base of the ladder, AI performs a discrete mechanical task with minimal human input beyond initiation, for example, automatically generating captions for a recorded lecture or transcribing a radio-style audio lesson. This rung reproduces conventional automation logic: the task is completed faster, but the process and the pedagogical framing remain unchanged. Automated substitution has legitimate uses, particularly for accessibility functions such as captioning, but the AITIE conference theme cautions against treating it as the destination of AI adoption in education.

Rung 2: Augmented Assistance

At this rung, AI generates a first-pass artefact, a draft narration script, a set of illustrative images, a rough voice-over, that a human educator substantially reviews, corrects, and reshapes before use, in a manner directly analogous to a broadcast sub-editor working from a wire-service draft. The human contribution shifts from originating every element to curating and refining AI-generated material against pedagogical and curricular standards.

Rung 3: Collaborative Co-Creation

Here, human and AI move through multiple iterative cycles, each shaping the other's contribution: the educator specifies intent and constraints, the AI generates options, the educator selects and redirects, and the cycle repeats until the artefact reflects a genuinely joint authorship. This rung most closely matches the newsroom or studio production dialogue between a producer and a scriptwriter, where successive drafts are shaped through structured back-and-forth rather than a single hand-off.

Rung 4: Redefined Ecosystems

At the highest rung, AI-assisted co-creation enables instructional media formats that would not have been feasible under prior production constraints, for instance, dynamically personalised broadcast-style lessons generated to match an individual learner's prior knowledge, language preference, or pace, produced through ongoing human-AI collaboration rather than a one-size-fits-all master recording. This rung corresponds to the 'redefinition' level of SAMR and represents the deepest alignment with the AITIE theme's call to reimagine, rather than merely digitise, teaching and learning ecosystems.

Discussion and Implications for Practice

The Augmentation Ladder carries several implications for reimagining teaching and learning ecosystems in Nigerian higher education and TVET. First, institutional AI adoption strategies should be explicit about which rung a given practice occupies, and should set deliberate goals for moving educators from automated substitution toward collaborative co-creation, rather than treating any AI use as equivalent progress. Second, faculty development programmes should be redesigned to build the specific skills each rung demands, from basic prompt literacy at the lower rungs to sustained iterative direction and quality-assurance judgement at the collaborative co-creation rung, echoing the editorial disciplines long taught in broadcast journalism training. Third, TVET curricula preparing media and educational technology practitioners should treat the ladder as a progression map, sequencing training so that learners move deliberately from automation-literacy toward augmentation fluency.

The broadcasting analogy also carries a caution: augmentation is not automatic simply because a human remains nominally in the loop. Broadcast history includes cautionary cases where over-reliance on automated systems degraded editorial quality; the same risk applies to educational media produced hastily at the automated-substitution rung and mistaken for genuine co-creation. Institutions reimagining their teaching and learning ecosystems for the AI era should therefore treat rung 4 (redefined ecosystems) as an aspiration built on disciplined practice at the lower rungs, not a shortcut around them.

Ethical and Quality Considerations

As with any AI-assisted production process, questions of authenticity, bias, intellectual property, and accessibility attend every rung of the ladder, but they intensify as collaboration deepens. At the collaborative co-creation and redefined ecosystems rungs, where AI contributes more substantially to the final artefact, transparency with learners about the extent of AI involvement, deliberate bias review of AI-generated narration and imagery, and clear institutional policy on authorship and intellectual property become increasingly important (Kasneci et al., 2023; UNESCO, 2021). Equitable access to the tools required for higher rungs of the ladder also raises digital divide concerns that institutions must address if augmentation is not to become available only to well-resourced departments.

Conclusion and Recommendations

This paper has taken up the AITIE conference's call to reimagine teaching and learning ecosystems by moving 'from automation to augmentation,' applying that call specifically to the practice of educational media co-creation. Building on Licklider's (1960) man-computer symbiosis, Engelbart's (1962) augmentation framework, and Puentedura's (2006) SAMR model, and drawing on broadcasting practice as a historical template for sustained human editorial authority amid technological change, the paper has proposed a four-rung Human-AI Augmentation Ladder, automated substitution, augmented assistance, collaborative co-creation, and redefined ecosystems, as a conceptual tool for naming and guiding the depth of human-AI collaboration in educational media production.

It is recommended that: (a) the proposed ladder be empirically tested through case studies of educators producing media at different rungs across Nigerian tertiary institutions; (b) institutional AI-adoption policies name explicit target rungs for different media production contexts rather than treating all AI use as equivalent; (c) faculty development programmes sequence training to build the specific skills each rung requires; and (d) further AITIE scholarship explore how the automation-to-augmentation distinction applies to other domains of the teaching and learning ecosystem beyond media production. Reimagining these ecosystems for the AI era, this paper argues, depends less on the sophistication of the AI systems adopted than on the deliberateness with which institutions and educators choose to climb from automation toward genuine augmentation.

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BEYOND TPACK: RECONCEPTUALISING CHEMISTRY TEACHER COMPETENCE THROUGH THE LEVEL-EXTENT ASSESSMENT FRAMEWORK FOR SUSTAINABLE SCIENCE EDUCATION IN NIGERIA

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Abstract

Science education plays a vital role in Nigeria's efforts to achieve technological advancement, industrial development, and sustainable national growth. Chemistry is a key science subject because it provides the foundation for many science-related careers and promotes scientific literacy. However, students' performance in chemistry in Nigerian secondary schools has remained consistently poor despite curriculum reforms and efforts to improve teaching. This situation suggests the need to examine teacher competence more closely. Although the Technological Pedagogical Content Knowledge (TPACK) framework has been widely used to assess teachers' ability to integrate technology, pedagogy, and content, it assumes that teachers' knowledge naturally leads to effective classroom practice. This assumption does not adequately reflect the realities of resource-constrained educational settings such as Nigeria, where inadequate laboratories, unreliable electricity, limited digital infrastructure, and insufficient professional support often restrict teachers' ability to implement what they know. This position paper argues that teacher competence should be understood through two complementary dimensions: Level, which refers to teachers' professional knowledge and mastery of chemistry, pedagogy, and technology, and Extent, which refers to the degree to which this knowledge is translated into effective classroom practice. Building on the TPACK framework, the paper proposes the Level–Extent Competency Framework (LECF) as a context-sensitive model for assessing chemistry teacher competence. The framework recognises that contextual factors mediate the relationship between teacher knowledge and instructional practice. It is expected to provide a more comprehensive basis for teacher assessment, professional development, educational policy, and the improvement of sustainable science education in Nigeria and other developing countries.

Keywords: Chemistry education; TPACK; teacher competence; sustainable science education; Level–Extent Competency Framework (LECF).

Introduction

Science education has long been recognised as one of the most important drivers of socioeconomic transformation, technological innovation, and sustainable national development. Nations that have achieved significant industrial and technological progress have consistently invested in strengthening science education through curriculum reform, teacher development, and educational innovation. Contemporary scholarship emphasises that science education contributes not only to scientific literacy but also to the development of problem-solving abilities, innovation capacity,

and human capital required for national advancement (Emeka et al., 2023; Olofin et al., 2023; Tijani & Adeduyigbe, 2025). Nigeria equally recognises this strategic role, with science and technology education positioned as a foundation for producing a skilled workforce capable of supporting national development and global competitiveness (Ogbonnaya & Abosede, 2020; Olofin et al., 2023). Within this national vision, secondary education occupies a particularly strategic position because it serves as the bridge between foundational education and higher education. At this level, learners develop scientific reasoning, critical thinking, creativity, and problem-solving abilities that prepare them for specialised study and future employment (Alarcon et al., 2023; Najjar & Daher, 2023). Consequently, the effectiveness of science education at the secondary school level depends substantially on the competence of classroom teachers, whose instructional decisions influence learners' conceptual understanding, attitudes toward science, and achievement outcomes (Canuto et al., 2024; Ofodu & Jımola, 2024).

Among the science subjects offered in Nigerian secondary schools, chemistry occupies a unique position because it connects theoretical scientific principles with practical applications in medicine, agriculture, environmental sustainability, engineering, industrial production, and biotechnology. Chemistry education contributes significantly to scientific and technological advancement because it provides learners with knowledge necessary for understanding materials, chemical processes, and industrial applications (Ameen, 2023; Tayo, 2025). However, chemistry also presents distinctive learning challenges because students must simultaneously interpret macroscopic phenomena, microscopic representations, and symbolic explanations of matter. Learners are required to understand molecular structures, chemical equations, atomic interactions, energy transformations, and laboratory investigations while relating abstract concepts to everyday experiences (Laohapornchaiphan & Chenprakhon, 2024; Thoms et al., 2026). Consequently, chemistry is widely regarded as one of the more cognitively demanding science subjects, requiring carefully designed instructional approaches that support conceptual understanding and meaningful learning (Byusa et al., 2022; Krajcik & Shin, 2023).

The inherent complexity of chemistry places considerable responsibility on teachers. Effective chemistry teaching extends beyond transmitting factual knowledge or preparing students for external examinations. Rather, it requires teachers to transform abstract scientific concepts into meaningful learning experiences through appropriate pedagogical strategies, practical laboratory activities, conceptual models, analogies, inquiry-based investigations, formative assessment, and digital technologies (Busch et al., 2022; Ralph et al., 2022; Wohlfart et al., 2023). Research in science education indicates that inquiry-oriented approaches, laboratory experiences, and technology-supported learning environments can enhance students' conceptual understanding, scientific reasoning, and engagement when effectively implemented (Alarcon et al., 2023; Shana & Abulibdeh, 2020; Rahman et al., 2024). Teachers therefore require sophisticated professional knowledge that integrates disciplinary expertise, pedagogy, and technological competence simultaneously (Mishra & Koehler, 2006; Koehler & Mishra, 2009).

Unfortunately, evidence accumulated over several decades suggests that chemistry instruction in many Nigerian secondary schools continues to face significant challenges. Studies conducted in Nigeria and other African educational contexts indicate that science teaching is often constrained by inadequate instructional resources, limited laboratory facilities, insufficient teacher professional development, large class sizes, and challenges associated with technology integration (Akpomiemie, 2025; Alema et al., 2024; Gambari & Yusuf, 2021). These limitations frequently encourage teacher-centred instructional approaches, where students receive information primarily

through explanation and memorisation rather than through inquiry, experimentation, and active knowledge construction (Hinampas & Fajardo, 2024; Woods & Copur-Gencturk, 2024). In chemistry classrooms specifically, inadequate practical resources and limited opportunities for technology-supported learning may restrict students' ability to connect abstract chemical concepts with observable phenomena and real-world applications (Akinkuotu & Aliyu, 2025; Ortega et al., 2024).

Numerous studies have reported that chemistry teachers' instructional practices are influenced by their professional knowledge, confidence, available resources, and opportunities for continuous development. Research on chemistry teachers in Nigeria has highlighted variations in teachers' content knowledge, pedagogical competence, technological knowledge, and ability to integrate these domains effectively during instruction (Adebusuyi et al., 2020; Bello & Ibiwumi, 2022; Ibrahim & Lawal, 2023). Similarly, studies examining technology integration among science teachers indicate that although many teachers recognise the value of digital tools, actual classroom implementation is frequently limited by infrastructure constraints, inadequate training, and contextual barriers (Abedi, 2023; Vaughan et al., 2023; Olayiwola & Adebayo, 2024). These challenges frequently encourage memorisation rather than conceptual understanding and limit students' ability to transfer scientific knowledge to authentic situations (Okafor, 2021; Musengimana et al., 2021).

WAEC concerns → TPACK theoretical foundation

These instructional deficiencies are reflected in recurring patterns observed in students' performance in national chemistry examinations. Reports from examination bodies such as the West African Examinations Council (WAEC) have consistently highlighted challenges including inadequate conceptual understanding, weak application of scientific principles, inaccurate use of chemical terminology, poor interpretation of chemical equations, and limited practical competence among secondary school candidates (Nweze & Obu, 2022; Obafemi & Ugonwa, 2025). These persistent difficulties suggest that improving chemistry achievement requires attention not only to learner characteristics but also to the quality of instructional processes, teacher competence, and the conditions under which teaching occurs (Al-Tameemi et al., 2023; Canuto et al., 2024). Consequently, contemporary research increasingly emphasises that enhancing science learning outcomes requires strengthening teachers' professional knowledge, instructional decision-making, and capacity to design meaningful learning experiences (Darling-Hammond et al., 2023; Ventista & Brown, 2023).

Historically, research explaining students' performance in chemistry has concentrated primarily on learner characteristics, instructional methods, school resources, or assessment practices. While these studies have generated valuable insights, they often examine isolated variables without fully considering the integrated professional competence required of chemistry teachers in contemporary classrooms (Sarkar et al., 2024; Zhang & Tian, 2024). Increasingly, educational researchers recognise that effective teaching depends not merely on what teachers know individually about chemistry, pedagogy, or technology, but on how these knowledge domains interact during classroom instruction (Shulman, 1986; Mishra & Koehler, 2006). The complexity of modern classrooms, characterised by diverse learners, digital learning environments, and increasing demands for learner-centred instruction, requires teachers to combine multiple forms of knowledge when making instructional decisions (Kastorff & Stegmann, 2024; Zhang & Li, 2025).

The Technological Pedagogical Content Knowledge (TPACK) framework proposed by Mishra and Koehler (2006) has therefore emerged as one of the most influential theoretical models for understanding teacher competence in technology-enhanced education. Building upon Shulman's (1986) concept of pedagogical content knowledge (PCK), the framework argues that effective teaching requires the dynamic integration of three primary knowledge domains: content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK). Their interactions generate additional forms of professional knowledge, including pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and the integrated technological pedagogical content knowledge (TPACK) construct (Koehler & Mishra, 2009; Schmidt et al., 2009).

Within science education, TPACK provides a valuable framework for understanding how teachers select, adapt, and apply instructional strategies and technological tools to represent complex scientific ideas. Chemistry teaching particularly benefits from this integrated knowledge perspective because many chemical concepts require multiple representations, including molecular models, simulations, symbolic equations, visualisations, and laboratory experiences (Deng et al., 2023; Hayati et al., 2022). Studies have demonstrated that teachers with stronger TPACK are more likely to design technology-supported learning activities, facilitate inquiry-based instruction, and employ representations that improve students' conceptual understanding of scientific phenomena (Jammeh et al., 2023; Shambare & Jita, 2024).

Over the past two decades, TPACK has become one of the most extensively applied frameworks in educational research, teacher education, and professional development across numerous subject disciplines, including science education (Lee et al., 2022; Sierra et al., 2023). Research reviews and empirical studies indicate that TPACK-oriented teacher education programmes can improve teachers' confidence, technological integration skills, instructional planning abilities, and professional awareness of technology-supported pedagogy (Ning et al., 2022; Diamah et al., 2022). In chemistry education specifically, TPACK has been used to examine teachers' readiness to integrate digital simulations, virtual laboratories, learning management systems, data-logging tools, and other emerging technologies into classroom practice (Imaduddin & Astuti, 2022; Deng et al., 2023; Kayumov et al., 2025).

Studies consistently demonstrate that teachers with stronger technological, pedagogical, and content knowledge tend to create richer learning environments, integrate digital technologies more effectively, promote higher-order thinking, and support deeper conceptual understanding among learners (Aldalalah et al., 2025; Celik, 2023; Gacayan, 2025). Consequently, TPACK has become an influential framework for curriculum development, teacher preparation, instructional design, and educational technology integration worldwide (Lee et al., 2022; Ning et al., 2024). However, despite its significant contributions, scholars have increasingly recognised that possessing integrated professional knowledge does not automatically guarantee successful classroom implementation, particularly in educational contexts where structural and environmental barriers influence teaching practice (Abedi, 2023; Nguyen et al., 2025).

TPACK limitations → LEAF framework → implications

Despite these significant contributions, important conceptual limitations remain, particularly when TPACK is applied within developing educational systems. Much of the existing TPACK literature implicitly assumes that teachers who possess strong technological, pedagogical, and content knowledge will naturally translate such knowledge into effective classroom practice. However, recent research suggests that the relationship between teacher knowledge and instructional enactment is complex and mediated by contextual factors, including institutional support, infrastructure availability, policy environments, professional development opportunities, and teachers' working conditions (Abedi, 2023; Fitrah et al., 2025; Mafa & Govender, 2025). Thus, while TPACK provides a powerful explanation of the knowledge required for effective technology integration, it offers comparatively less explanation of how external conditions influence teachers' ability to operationalise that knowledge in real classrooms.

This limitation becomes particularly important in educational contexts characterised by inadequate infrastructure, unreliable electricity supply, limited internet connectivity, insufficient laboratory facilities, overcrowded classrooms, heavy teaching workloads, and restricted access to continuous professional development. Such challenges remain prevalent within many Nigerian secondary schools and significantly influence teachers' opportunities to implement innovative instructional practices (Akpomiemie, 2025; Gambari & Yusuf, 2021; Mitchell et al., 2024). In these environments, teachers may possess relevant professional knowledge but remain unable to demonstrate its full application because systemic constraints restrict implementation possibilities (Abedi, 2023; Vaughan et al., 2023).

For example, a chemistry teacher may understand the pedagogical value of molecular simulation software, virtual laboratories, or digital representations of chemical processes but lack access to computers, reliable electricity, internet connectivity, or institutional support necessary for classroom application (Akinkuotu & Aliyu, 2025; Wohlfart et al., 2023). Similarly, a teacher may possess sophisticated knowledge of inquiry-based laboratory instruction but work in a school where functional laboratories, chemical reagents, safety equipment, or practical instructional resources are unavailable (Alema et al., 2024; Shana & Abulibdeh, 2020). Under such circumstances, conventional TPACK assessments may risk interpreting limited classroom technology use as a deficiency in teacher competence without sufficiently accounting for contextual barriers that constrain instructional enactment.

This distinction between professional knowledge and professional enactment has received increasing attention in teacher competence research. Contemporary perspectives argue that teacher effectiveness is not determined solely by individual knowledge structures but emerges through interactions among teacher characteristics, instructional environments, institutional conditions, and opportunities for professional learning (Bürger et al., 2026; Zhang & Tian, 2024). Similarly, research on teacher professional development indicates that sustainable improvements in teaching practice require alignment between teacher capacity building and supportive educational environments that enable teachers to apply newly developed competencies (Darling-Hammond et al., 2023; Ventista & Brown, 2023).

This paper therefore argues that an important theoretical gap exists within contemporary teacher competence literature. Existing TPACK scholarship provides a comprehensive conceptualisation of what teachers should know; however, it provides comparatively limited explanation of the extent to which such knowledge can be enacted under different educational conditions. The assumption that knowledge automatically produces practice overlooks the contextual mediation of teaching and may consequently underestimate teachers' professional capacity within resource-constrained educational systems (Abedi, 2023; Nguyen et al., 2025). Understanding chemistry teacher competence therefore requires a framework that considers not only the level of professional knowledge possessed by teachers but also the extent to which that knowledge is expressed through observable classroom practice.

To address this limitation, this position paper proposes the Level–Extent Assessment Framework (LEAF) as a conceptual extension of TPACK. The framework distinguishes between two complementary dimensions of teacher competence. The first dimension, level, represents teachers' cognitive mastery and professional capability across content knowledge, pedagogical knowledge, technological knowledge, and integrated TPACK. This dimension reflects the internal knowledge structures that teachers develop through education, experience, and professional learning (Mishra & Koehler, 2006; Shulman, 1986). The second dimension, extent, represents the observable degree to which teachers enact these competencies through technological integration, pedagogical implementation, classroom practices, assessment strategies, and instructional decision-making within prevailing contextual conditions (Danielson, 2007; González-Fernández et al., 2024).

By separating internal professional competence from external instructional enactment, LEAF provides a more nuanced approach to understanding chemistry teacher effectiveness within developing educational contexts. Rather than treating competence as a single measurable attribute, the framework recognises that effective teaching emerges through the interaction between teachers' professional knowledge and the opportunities available for implementing that knowledge (Sarkar et al., 2024; Zhang & Tian, 2024). This perspective aligns with broader competency-based approaches that view teaching expertise as a combination of knowledge, skills, dispositions, and context-sensitive professional actions (Alan & Güven, 2022; Real, 2022).

The proposed reconceptualisation has significant implications for teacher assessment, professional development, educational policy, school leadership, and sustainable science education. For teacher assessment, LEAF encourages movement beyond knowledge-based measurement toward evaluation systems that examine both teacher capability and classroom enactment. For professional development, it highlights the importance of designing programmes that strengthen teachers' knowledge while simultaneously addressing environmental barriers that limit implementation (Ning et al., 2022; Mitchell et al., 2024). For educational policy, it emphasises that improving science education requires investment not only in teacher preparation but also in the infrastructure, resources, and institutional support necessary for teachers to apply their expertise effectively.

Ultimately, strengthening chemistry education in Nigeria requires moving beyond measuring what teachers know toward understanding how educational environments enable—or constrain—the translation of professional knowledge into meaningful classroom practice. Such a shift is essential if teacher competence assessments are to support evidence-based reforms capable of improving

science teaching, enhancing student learning outcomes, and advancing Nigeria's broader aspirations for sustainable scientific and technological development (Tijani & Adeduyigbe, 2025; Ugwuanyi et al., 2026).

Why Existing TPACK Assessment Is Inadequate

Although the TPACK framework has significantly advanced understanding of teacher knowledge for technology-supported teaching, existing approaches to assessing TPACK have several conceptual and methodological limitations that reduce their explanatory power, particularly within complex educational environments such as Nigerian secondary schools. Most existing TPACK assessment approaches were developed around the assumption that the different knowledge domains within the framework contribute relatively equally to teachers' overall technological teaching competence. Consequently, many assessment instruments measure technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), and their intersections as separate but equally weighted constructs, often producing composite scores that treat competence as an additive rather than an interactive phenomenon (Schmidt et al., 2009; Lee et al., 2022). While this approach has contributed to understanding teachers' perceived knowledge levels, it may overlook the possibility that certain knowledge domains are more influential than others depending on subject area, educational context, available resources, and instructional demands (Sarkar et al., 2024; Zhang & Tian, 2024).

In chemistry education, for example, possessing technological knowledge alone may have limited instructional value if teachers lack adequate chemistry content knowledge, pedagogical strategies for representing abstract concepts, or opportunities to apply digital tools within laboratory-based learning environments. Effective chemistry instruction requires teachers to coordinate multiple forms of knowledge, including understanding students' misconceptions, selecting appropriate representations of chemical phenomena, designing meaningful laboratory experiences, and determining when technological tools genuinely enhance conceptual understanding (Gencer & Akkus, 2021; Hayati et al., 2022). Therefore, treating all TPACK components as equally weighted constructs may fail to capture the disciplinary and contextual complexity of chemistry teaching.

Furthermore, many existing TPACK assessment approaches focus primarily on measuring teachers' perceived knowledge rather than their actual classroom practices. Self-report questionnaires remain one of the most common methods used to assess TPACK, allowing researchers to examine teachers' confidence and perceptions regarding their technological, pedagogical, and content knowledge (Schmidt et al., 2009; Ning et al., 2022). However, evidence suggests that perceived competence does not always correspond with observable instructional behaviour. Teachers may report high levels of confidence in technology integration while making limited use of technology in authentic classroom situations due to institutional constraints, limited resources, inadequate infrastructure, or competing professional demands (Bui, 2022; Abedi, 2023). This discrepancy highlights a major limitation of assessment approaches that measure what teachers believe they know without sufficiently examining how such knowledge is enacted in practice.

A second limitation of existing TPACK assessment is the insufficient consideration of educational context. Much of the TPACK literature conceptualises teacher knowledge as an individual

cognitive capability while paying comparatively less attention to the environmental conditions that enable or restrict the use of that knowledge (Mishra & Koehler, 2006; Celik, 2023). However, teaching is inherently situated, and teachers' ability to implement technology-supported instruction depends heavily on contextual factors such as school infrastructure, availability of instructional materials, leadership support, curriculum expectations, class size, internet accessibility, and opportunities for professional learning (Abedi, 2023; Kastorff & Stegmann, 2024).

This contextual limitation is particularly significant in developing educational systems, including Nigeria, where teachers frequently operate within environments characterised by resource shortages, inconsistent electricity supply, inadequate laboratory facilities, limited access to digital technologies, and insufficient institutional support for innovation (Gambari & Yusuf, 2021; Akpomiemie, 2025). In such settings, low levels of technology integration may not necessarily indicate inadequate teacher knowledge or poor professional competence. Rather, they may reflect structural limitations that prevent teachers from converting their knowledge into classroom practices (Vaughan et al., 2023; Olayiwola & Adebayo, 2024). Consequently, assessments that ignore context risk producing inaccurate interpretations of teacher competence by attributing implementation challenges solely to individual teachers.

Another critical assumption underlying many TPACK assessment models is that knowledge automatically leads to implementation. The traditional interpretation of TPACK suggests that when teachers possess sufficient technological, pedagogical, and content knowledge, they will be better positioned to integrate technology effectively into instruction (Koehler & Mishra, 2009). While this relationship is theoretically reasonable, empirical evidence indicates that the transition from knowledge possession to classroom enactment is not automatic. Teachers' instructional decisions are influenced by confidence, beliefs, school culture, curriculum pressures, assessment demands, availability of resources, and perceived usefulness of technologies (Abedi, 2023; Mafa & Govender, 2025).

For chemistry teachers, the distinction between knowledge and implementation is particularly important because effective technology integration often requires alignment between digital resources and specific scientific learning goals. A teacher may understand how virtual simulations, molecular modelling applications, or digital assessment tools function but may not integrate them effectively unless they can identify appropriate pedagogical purposes and adapt them to learners' conceptual difficulties (Deng et al., 2023; Jammeh et al., 2023). Therefore, technology integration should be understood not simply as a reflection of teacher knowledge but as a complex process involving professional judgement, classroom realities, and available opportunities for enactment.

Additionally, existing TPACK assessment frameworks have been criticised for insufficiently representing the realities of teachers working in African educational contexts. Much of the empirical TPACK literature has emerged from technologically developed educational systems where assumptions about infrastructure availability, digital access, and institutional support may not align with the experiences of teachers in many African countries (Nguyen et al., 2025; Mitchell et al., 2024). Consequently, assessment frameworks developed within these contexts may inadequately capture the challenges faced by teachers working in environments where access to technology is uneven and educational resources remain constrained.

African education systems present distinctive realities, including digital divides between urban and rural schools, limited access to professional development, inadequate science laboratories, and differences in policy implementation capacity (Gambari & Yusuf, 2021; Mitchell et al., 2024). Research on Nigerian secondary school science teachers demonstrates that technology adoption is often shaped not only by teachers' competence but also by access to infrastructure, school-level support, and broader educational conditions (Bello & Ibiwumi, 2022; Vaughan et al., 2023). Therefore, applying conventional TPACK assessments without considering these contextual realities may provide incomplete or misleading evaluations of teacher capability.

The limitations identified above indicate the need for a more context-sensitive approach to assessing teacher competence. Rather than viewing TPACK solely as a measure of what teachers know, assessment frameworks should distinguish between teachers' capacity for effective instruction and their opportunities to demonstrate that capacity in practice. Such an approach would recognise that teacher competence exists across multiple levels, including internal knowledge development and external instructional enactment. The proposed Level–Extent Assessment Framework (LEAF) responds to this limitation by extending TPACK assessment beyond knowledge measurement toward a more comprehensive understanding of how professional competence is expressed within real educational environments. This perspective is particularly relevant for chemistry education in Nigeria, where improving instructional quality requires not only developing teacher knowledge but also creating the conditions necessary for teachers to apply that knowledge effectively.

Theoretical Gap: The Missing Bridge Between Knowledge and Teaching Practice

Although the TPACK framework has significantly advanced understanding of teacher competence, its dominant conceptualisation contains an important theoretical limitation. The framework primarily explains what teachers need to know for effective technology-integrated teaching but provides insufficient explanation of how this knowledge is transformed into classroom practice within specific educational environments. In its conventional interpretation, TPACK assumes a relatively direct relationship between teachers' professional knowledge and instructional practice, suggesting that increased knowledge of content, pedagogy, and technology should naturally lead to improved teaching outcomes.

The underlying assumption can therefore be represented as:

Current TPACK assumption:

Knowledge → Teaching

Within this perspective, teachers who demonstrate high levels of technological knowledge, pedagogical knowledge, content knowledge, and their intersections are expected to implement effective technology-supported instruction. Consequently, many TPACK assessment instruments focus primarily on measuring teachers' perceived competence across the different knowledge domains, often treating knowledge possession as a reliable indicator of classroom effectiveness (Mishra & Koehler, 2006; Schmidt et al., 2009; Koehler et al., 2014).

However, this linear assumption becomes problematic when applied within educational contexts where institutional, infrastructural, and sociocultural conditions significantly influence what teachers can realistically implement. Teaching practice does not occur in an abstract environment; rather, it is embedded within complex systems involving school resources, curriculum demands, leadership support, class size, availability of instructional materials, electricity supply, internet access, professional development opportunities, and broader educational policies. Therefore, possessing professional knowledge does not automatically guarantee the opportunity or capacity to enact that knowledge effectively (Porras-Hernández & Salinas-Amescua, 2013; Rosenberg & Koehler, 2015).

A more realistic representation of teacher competence in diverse educational contexts requires the inclusion of an intermediate contextual dimension. Proposed theoretical relationship:

Knowledge → Context → Teaching

The missing theoretical bridge between knowledge and teaching is contextual enactment. This bridge recognises that teacher knowledge must pass through a process of interpretation, adaptation, negotiation, and implementation that is shaped by the realities of the teaching environment. The effectiveness of a teacher's competence therefore depends not only on the knowledge possessed but also on the extent to which the surrounding educational conditions enable that knowledge to be converted into meaningful classroom practices.

This limitation is particularly significant within developing educational systems such as Nigeria, where science teachers frequently operate under conditions that differ substantially from those assumed in many TPACK studies conducted in technologically advanced contexts. For example, a chemistry teacher may possess strong technological content knowledge regarding molecular modelling applications but may be unable to integrate such tools because of inadequate computer facilities, unreliable electricity supply, limited internet connectivity, or lack of institutional support. Similarly, a teacher may demonstrate advanced pedagogical knowledge of inquiry-based chemistry instruction but may be constrained by overcrowded classrooms, insufficient laboratory equipment, or examination-driven instructional pressures.

These realities indicate that teacher competence should not be conceptualised solely as an internal possession of knowledge but as a dynamic relationship between professional capability and opportunities for enactment. As argued within broader teacher knowledge research, professional competence involves both what teachers know and how they apply that knowledge within particular educational circumstances (Shulman, 1986; Shulman, 1987). Consequently, contextual factors should not be treated merely as external variables influencing TPACK implementation but as essential components that determine whether teacher knowledge can become effective classroom action.

The absence of this contextual bridge creates several theoretical and methodological challenges. First, conventional TPACK assessments may underestimate teachers' professional competence by interpreting limited technology integration as evidence of inadequate knowledge rather than as a consequence of environmental constraints. Second, such assessments may overestimate the practical implications of teacher knowledge by assuming that high self-reported TPACK

automatically translates into improved instructional practice. Third, they provide limited guidance for educational policymakers because they identify knowledge deficiencies without adequately explaining the systemic conditions required for teachers to apply their knowledge effectively.

Therefore, extending TPACK requires a shift from viewing competence as a static collection of knowledge domains toward understanding competence as an interaction between knowledge capacity and contextual possibility. The proposed Level–Extent Assessment Framework (LEAF) addresses this theoretical gap by distinguishing between the level of professional knowledge teachers possess and the extent to which such knowledge is enacted within real classroom environments. Through this distinction, LEAF provides a more context-sensitive explanation of chemistry teacher effectiveness, particularly within resource-constrained educational systems.

By introducing context as a mediating mechanism between teacher knowledge and instructional practice, this framework advances contemporary discussions of teacher competence beyond the question of *what teachers know* toward the more critical question of *how educational environments enable teachers to use what they know*. Such a reconceptualisation provides a stronger theoretical foundation for evaluating, developing, and supporting science teachers in contexts where educational realities substantially shape the possibilities of effective teaching.

Introducing the Level–Extent Framework (LEAF)

The limitations identified within conventional TPACK assessment necessitate a reconceptualisation of teacher competence that distinguishes between what teachers know and how extensively they are able to apply that knowledge within authentic classroom environments. The proposed Level–Extent Assessment Framework (LEAF) addresses this distinction by conceptualising teacher competence as a multidimensional construct consisting of two complementary dimensions: level and extent. While the level dimension captures teachers' internal professional capacity, the extent dimension examines the degree to which that capacity is translated into observable instructional practice under prevailing contextual conditions.

The level dimension refers to the depth, quality, and sophistication of a teacher's professional knowledge and cognitive capability within a particular instructional domain. It represents the extent to which teachers possess conceptual understanding, procedural knowledge, and professional expertise required for effective teaching. This dimension aligns with established perspectives on teacher knowledge, particularly Shulman's (1986, 1987) argument that effective teaching requires specialised forms of professional understanding that combine disciplinary knowledge with pedagogical reasoning. Within the TPACK framework, level corresponds to teachers' mastery of content knowledge (CK), pedagogical knowledge (PK), technological knowledge (TK), and the integrated knowledge domains that emerge from their interaction (Mishra & Koehler, 2006).

Operationally, level is defined as the degree of cognitive mastery and professional proficiency demonstrated by a teacher in understanding, explaining, evaluating, and designing instructional approaches within a subject area. It reflects teachers' theoretical competence, including their ability to understand scientific concepts, select appropriate pedagogical approaches, evaluate technological tools, and make informed instructional decisions. In chemistry education, for

example, a teacher with a high level of competence should demonstrate strong understanding of chemical principles, recognise common student misconceptions, select suitable representations of abstract concepts, and identify appropriate technological or laboratory resources that support conceptual learning.

The level dimension therefore focuses on internal competence indicators such as:

- Cognitive mastery: the depth of conceptual understanding and ability to reason effectively within the subject domain;
- Professional proficiency: the ability to apply specialised knowledge in planning, explaining, and evaluating instruction;
- Theoretical competence: possession of the conceptual frameworks and principles necessary for informed pedagogical decision-making.

This dimension does not assume that high knowledge automatically results in effective teaching practice. Rather, it identifies the professional capacity available to the teacher before considering the environmental conditions that may facilitate or constrain its enactment.

The second dimension, extent, refers to the observable manifestation of teacher competence in actual classroom practice. While level examines teachers' knowledge capacity, extent examines the degree to which this capacity is implemented, sustained, and adapted within real instructional contexts. This distinction responds to concerns within educational technology research that knowledge assessments alone may provide an incomplete picture of teacher effectiveness because implementation is influenced by contextual factors such as infrastructure, institutional support, curriculum requirements, and resource availability (Porras-Hernández & Salinas-Amescua, 2013; Rosenberg & Koehler, 2015).

Operationally, extent is defined as the degree, frequency, consistency, and contextual appropriateness with which teachers translate their professional knowledge into observable classroom actions. It represents the practical enactment of competence through instructional behaviours, technology integration practices, classroom interactions, and decision-making processes. For chemistry teachers, extent may include how frequently teachers employ laboratory investigations, integrate digital simulations, use inquiry-based approaches, facilitate student-centred learning activities, and adapt instructional strategies to address learners' conceptual difficulties.

The extent dimension incorporates four major indicators:

- Implementation: the actual application of professional knowledge through instructional strategies, technological tools, assessment practices, and classroom activities;
- Frequency: the regularity with which effective teaching practices are employed rather than used occasionally or under special circumstances;
- Classroom behaviour: observable teacher actions, including facilitation of discussion, use of representations, management of practical activities, and promotion of scientific reasoning;

- Contextual enactment: the extent to which teachers successfully adapt and apply their knowledge within the opportunities and limitations of their specific educational environment.

The distinction between level and extent introduces a more nuanced understanding of teacher competence. Two teachers may possess similar levels of professional knowledge but demonstrate different extents of classroom enactment because they operate within different contextual conditions. For example, two chemistry teachers may both understand the value of molecular modelling software; however, the teacher working in a school with functional computer facilities, reliable electricity, and institutional support may demonstrate a higher extent of technology integration than a teacher working in a resource-constrained environment. The difference does not necessarily indicate a difference in competence level but rather reflects differences in opportunities for enactment.

Therefore, LEAF proposes that teacher effectiveness emerges from the interaction between professional capacity (level) and practical opportunity (extent). The framework moves beyond traditional approaches that treat competence as a single measurable attribute and instead recognises competence as a dynamic relationship between knowledge possession and instructional realisation. This approach provides a more context-sensitive model for evaluating chemistry teacher competence, particularly within developing educational systems where environmental conditions frequently influence the translation of professional knowledge into classroom practice.

By separating level from extent, LEAF offers a stronger theoretical and practical foundation for teacher assessment, professional development, and educational policy. It enables researchers and policymakers to identify whether instructional challenges arise from insufficient teacher knowledge or from contextual barriers that restrict the implementation of existing competence. Consequently, the framework supports more accurate diagnosis of teacher needs and more effective interventions aimed at improving science education outcomes.

Why Nigeria Needs the Level–Extent Framework

The need for the Level–Extent Assessment Framework (LEAF) becomes particularly evident when examining the realities of science education implementation within the Nigerian secondary school system. Although teacher competence remains a fundamental determinant of educational quality, the translation of professional knowledge into classroom practice is strongly influenced by the conditions under which teachers operate. In many Nigerian schools, particularly those in rural and underserved communities, teachers frequently experience structural and institutional constraints that limit their ability to implement the knowledge and pedagogical strategies they possess. Consequently, measuring teacher effectiveness solely through knowledge-based frameworks such as conventional TPACK assessments may provide an incomplete representation of actual classroom capability.

One of the most significant contextual barriers affecting technology-supported science teaching in Nigeria is electricity instability. Effective integration of digital technologies in chemistry education often requires reliable access to electricity for computers, interactive displays, internet connectivity, digital simulations, and other instructional devices. However, inconsistent electricity

supply remains a persistent challenge within many Nigerian educational institutions, limiting teachers' ability to incorporate technology regularly into classroom practice. Research on educational technology adoption in developing contexts indicates that infrastructure availability is a critical factor determining whether teachers can transform technological knowledge into practical classroom applications (Buabeng-Andoh, 2012; Rosenberg & Koehler, 2015). Therefore, a teacher's inability to use digital resources consistently may reflect environmental limitations rather than inadequate technological competence.

Similarly, shortages of laboratory facilities and instructional materials create significant barriers to effective chemistry teaching. Chemistry is a practical science that requires laboratory experiences, demonstrations, experimentation, and opportunities for students to connect theoretical concepts with observable phenomena. However, many Nigerian secondary schools experience inadequate laboratory spaces, insufficient chemical reagents, outdated equipment, and limited maintenance support. These conditions restrict teachers' ability to implement inquiry-based and practical pedagogies, even when they possess strong pedagogical knowledge regarding effective science instruction. Studies on science education in Nigeria have repeatedly identified inadequate laboratory resources as a major factor affecting students' conceptual understanding and achievement in chemistry (Akinbobola & Afolabi, 2010; Ogunleye, 2002).

Limited internet access and digital connectivity further complicate technology integration. Contemporary chemistry education increasingly benefits from online simulations, virtual laboratories, multimedia resources, digital assessment platforms, and collaborative learning environments. However, unequal access to internet infrastructure remains a major challenge, particularly in rural schools and disadvantaged communities. The digital divide influences not only whether technologies are available but also whether teachers have meaningful opportunities to practise and sustain technology-enhanced teaching approaches (Tondeur et al., 2017). Thus, a teacher may possess advanced technological pedagogical knowledge while lacking the digital environment required to demonstrate that competence in practice.

Teacher workload represents another important contextual factor influencing instructional enactment. Nigerian secondary school teachers often manage large teaching responsibilities, administrative duties, examination preparation requirements, and curriculum coverage expectations. Heavy workloads reduce the time available for lesson redesign, experimentation with innovative teaching approaches, professional learning, and development of technology-supported instructional materials. Research on teacher technology integration has shown that successful implementation depends not only on teacher knowledge but also on time, institutional support, and opportunities for professional engagement (Ertmer & Ottenbreit-Leftwich, 2010). Consequently, limited classroom innovation may result from competing professional demands rather than a lack of pedagogical capability.

The challenge is intensified by overcrowded classrooms, which remain common in many Nigerian secondary schools. Large class sizes make it difficult for teachers to employ student-centred approaches such as inquiry-based learning, collaborative investigations, laboratory activities, and formative assessment strategies. Even highly competent teachers may modify their instructional practices when faced with classrooms containing large numbers of students, limited teaching

assistants, and restricted instructional resources. Under such conditions, implementation becomes a negotiation between professional intentions and practical classroom realities.

These challenges are particularly pronounced in rural schools, where teachers often operate under more severe resource limitations than their urban counterparts. Rural schools may experience shortages of qualified science teachers, limited access to professional development opportunities, weaker technological infrastructure, and reduced institutional support. Such disparities demonstrate that teacher competence cannot be interpreted independently from the educational environments in which teachers work. A rural chemistry teacher and an urban chemistry teacher may possess comparable professional knowledge but demonstrate different levels of instructional enactment because their opportunities for implementation differ substantially.

Furthermore, educational policy and systemic implementation issues influence the extent to which teachers can apply their professional knowledge. Although Nigerian education policies emphasise science, technology, and innovation as priorities for national development, gaps often exist between policy expectations and actual school-level implementation. Effective curriculum reform requires alignment among teacher preparation, infrastructure provision, resource allocation, school leadership, and continuous professional development systems. Without such alignment, policies promoting technology integration and improved science education may remain aspirational rather than practically achievable (Federal Republic of Nigeria, 2013; UNESCO, 2015).

These realities highlight a fundamental distinction between competence and implementation. Competence refers to what teachers know, understand, and are capable of doing, whereas implementation reflects what teachers are able to enact within their specific educational contexts. The two dimensions are related but not identical. A teacher may demonstrate a high level of technological pedagogical content knowledge but exhibit limited classroom implementation because of unavailable infrastructure, inadequate resources, or institutional constraints. Conversely, a teacher working within supportive conditions may demonstrate extensive classroom enactment even with moderate levels of formal technological expertise.

Therefore, Nigeria requires a framework that recognises the difference between professional capacity and practical opportunity. LEAF responds to this need by separating the level of teacher competence from the extent of its enactment. This distinction prevents unfair assessments that attribute implementation challenges solely to teachers while ignoring systemic barriers that shape classroom possibilities. More importantly, it provides policymakers, teacher educators, and school administrators with clearer information about whether interventions should focus on improving teacher knowledge, strengthening educational infrastructure, or addressing institutional constraints.

By incorporating contextual realities into the assessment of teacher competence, LEAF offers a more appropriate model for understanding chemistry teaching effectiveness in Nigeria and other developing educational contexts. The framework acknowledges that improving science education requires not only developing knowledgeable teachers but also creating environments where those teachers can successfully transform knowledge into meaningful learning experiences.

Implications of the Level–Extent Assessment Framework (LEAF)

The introduction of the Level–Extent Assessment Framework (LEAF) has significant implications for multiple dimensions of science education, particularly in contexts where educational outcomes are influenced by both teacher competence and systemic conditions. By distinguishing between the level of professional knowledge teachers possess and the extent to which such knowledge is enacted within classroom practice, the framework provides a more comprehensive basis for understanding teacher effectiveness. This distinction has important consequences for teacher education, certification, appraisal, curriculum development, professional development, educational technology integration, and educational policy.

Implications for Teacher Education

Teacher education programmes have traditionally emphasised the development of subject knowledge and pedagogical skills, with increasing attention given to technological competence. However, LEAF suggests that preparing effective teachers requires moving beyond knowledge acquisition toward developing teachers' ability to translate knowledge into practice under diverse classroom conditions. Teacher preparation institutions should therefore design programmes that assess both competence development and opportunities for classroom enactment.

Within chemistry teacher education, this requires greater integration of disciplinary knowledge, pedagogical reasoning, technological skills, and contextual problem-solving. Pre-service teachers should not only learn how to use digital tools, laboratory methods, and inquiry-based approaches but also understand how these approaches can be adapted when resources are limited. Such preparation aligns with research indicating that effective technology integration depends on teachers' ability to make context-sensitive instructional decisions rather than merely possessing technological skills (Mishra & Koehler, 2006; Koehler et al., 2014).

Teacher education programmes should therefore incorporate authentic school experiences, classroom-based problem-solving activities, reflective practice, and exposure to different teaching environments. Developing teachers' capacity to analyse contextual constraints and design realistic instructional solutions would strengthen the connection between professional knowledge and classroom practice.

Implications for Teacher Certification

Current teacher certification systems often emphasise qualifications, examination performance, and demonstration of professional knowledge. While these remain important indicators of teacher preparedness, LEAF suggests that certification should also consider teachers' capacity for practical enactment. A teacher may possess extensive theoretical knowledge but still require support in applying that knowledge effectively within real classroom environments.

Certification processes could therefore incorporate multiple measures, including assessments of pedagogical reasoning, classroom observation, instructional design tasks, technology integration activities, and evidence of adaptive teaching practices. Such an approach would provide a more

valid representation of teacher competence by recognising both knowledge possession and instructional performance.

This perspective is consistent with broader arguments in teacher assessment research that effective evaluation requires examining not only what teachers know but also how they apply knowledge in authentic professional settings (Shulman, 1987; Darling-Hammond, 2012).

Implications for Teacher Appraisal

Teacher appraisal systems frequently focus on observable classroom performance, examination outcomes, or compliance with administrative requirements. Although classroom practice is essential, LEAF highlights the importance of distinguishing between limited implementation caused by inadequate competence and limited implementation caused by contextual barriers.

For example, a chemistry teacher who rarely uses digital simulations because of unavailable electricity or computers should not necessarily be evaluated in the same manner as a teacher who has access to such resources but chooses not to use them. Appraisal systems based on LEAF would examine both the teacher's professional capability and the environmental conditions affecting implementation.

This approach would encourage fairer evaluation systems that identify whether improvement efforts should focus on teacher learning, resource provision, institutional support, or policy intervention. It would also promote a developmental approach to appraisal rather than one based solely on accountability.

Implications for Curriculum Development

Curriculum development should recognise that curriculum expectations must correspond with the realities of classroom implementation. Science curricula increasingly emphasise inquiry-based learning, practical activities, digital literacy, and learner-centred approaches; however, successful implementation depends on teachers having both the competence and the contextual opportunity to enact these expectations.

LEAF suggests that curriculum designers should consider implementation feasibility during curriculum planning. Curriculum documents should include realistic guidance on adapting instructional strategies within different school contexts, particularly resource-constrained environments. In chemistry education, this may involve providing alternative approaches for laboratory activities, recommending low-cost instructional resources, and integrating locally available materials into practical learning experiences.

Such context-sensitive curriculum design would reduce the gap between curriculum intentions and classroom realities.

Implications for Professional Development

Professional development programmes often focus on improving teacher knowledge through workshops and training sessions. However, LEAF indicates that increasing knowledge alone may not produce meaningful changes in classroom practice unless teachers are also supported in applying that knowledge within their working environments.

Effective professional development should therefore address both dimensions of competence. Programmes should strengthen teachers' conceptual understanding and pedagogical skills while also providing opportunities for classroom experimentation, mentoring, peer collaboration, and follow-up support. Technology-focused professional development should move beyond introducing digital tools and instead emphasise how teachers can integrate technology meaningfully within specific subject areas and contextual limitations.

Research on teacher technology integration demonstrates that sustained, practice-based professional learning is more effective than isolated training sessions because it supports teachers in connecting new knowledge with classroom realities (Ertmer & Ottenbreit-Leftwich, 2010; Tondeur et al., 2017).

Implications for Educational Technology

LEAF challenges the assumption that providing technology automatically leads to improved teaching and learning outcomes. Technology integration depends on the interaction between teacher competence, technological availability, institutional support, and classroom conditions.

Educational technology initiatives should therefore move beyond measuring the availability of devices and instead evaluate the extent to which teachers are able to meaningfully incorporate technology into instructional practice. In contexts such as Nigeria, technology policies should consider issues such as electricity reliability, internet accessibility, technical support, teacher readiness, and sustainability.

This approach supports a more realistic understanding of technology integration by recognising that successful implementation requires alignment between technological resources and teachers' professional capacities (Rosenberg & Koehler, 2015).

Implications for Educational Policy

At the policy level, LEAF provides a framework for more accurate decision-making regarding science education improvement. Policies that focus exclusively on teacher training may overlook the structural conditions that restrict implementation. Conversely, policies that invest only in infrastructure without developing teacher capacity may fail to achieve sustainable instructional improvement.

Educational policies should therefore adopt a balanced approach that simultaneously strengthens teacher competence and improves the environments in which teachers work. This requires

coordinated investment in teacher education, school infrastructure, digital connectivity, laboratory facilities, professional development systems, and supportive leadership structures.

For Nigeria's aspirations toward scientific and technological advancement, improving chemistry education requires more than increasing teachers' knowledge. It requires creating conditions where teachers can effectively transform professional knowledge into classroom practice. LEAF contributes to this goal by providing a framework that connects teacher competence with contextual realities, enabling more accurate assessment, targeted intervention, and sustainable educational reform.

Future Research Directions

The proposed Level–Extent Assessment Framework (LEAF) represents a conceptual advancement in understanding teacher competence by distinguishing between teachers' professional knowledge and the extent to which such knowledge is enacted within authentic classroom contexts. However, as a theoretical extension of existing teacher knowledge frameworks, LEAF requires systematic empirical investigation to establish its validity, reliability, and explanatory capacity across diverse educational environments. Future research should therefore focus on generating evidence that can refine the framework and determine its contribution to teacher assessment, professional development, and science education improvement.

A primary research priority is the empirical validation of LEAF. Future studies should examine whether the two proposed dimensions, level and extent, represent distinct but interconnected components of teacher competence. Researchers should assess whether measures of cognitive mastery, professional knowledge, instructional implementation, classroom behaviours, and contextual enactment demonstrate acceptable reliability and validity. Mixed-method approaches combining questionnaires, classroom observations, interviews, lesson analyses, and performance-based assessments are recommended because previous research has shown that self-reported teacher knowledge measures may not always correspond with actual classroom practices (Abbitt, 2011; Rosenberg & Koehler, 2015).

Structural equation modelling (SEM) provides an appropriate methodological approach for testing the theoretical relationships proposed within LEAF. SEM can examine whether teachers' professional competence (level) predicts instructional enactment (extent) while determining the mediating or moderating influence of contextual factors such as technology availability, laboratory resources, institutional support, and professional development opportunities. Such analyses would provide empirical evidence for the central assumption of LEAF that teacher knowledge does not automatically translate into classroom practice but is shaped by enabling or constraining educational conditions.

Future research should also employ multilevel modelling (MLM) because teaching practice occurs within multiple levels of educational systems. Teacher competence is influenced not only by individual characteristics but also by school and policy environments. Multilevel investigations should therefore examine relationships among teacher-level factors, including content knowledge, pedagogical competence, technological knowledge, experience, and training; school-level factors such as laboratory facilities, infrastructure, leadership support, and class size; and broader system-

level factors including curriculum policies and regional differences. Such studies would clarify why teachers with similar professional knowledge may demonstrate different levels of classroom implementation.

Longitudinal research is equally important because teacher competence develops over time through experience, professional learning, and changing educational conditions. Existing TPACK studies have frequently relied on cross-sectional designs that provide limited understanding of how knowledge and practice evolve (Koehler et al., 2014). Long-term studies should investigate whether professional development programmes produce sustained changes in instructional practice, whether increased knowledge leads to continuous technology integration, and how improvements or declines in educational resources influence teachers' ability to enact their competence.

Cross-country comparative research would further strengthen the theoretical contribution of LEAF. Although the framework is particularly relevant to Nigeria and other developing educational systems, its applicability should be examined across different national contexts. Comparative studies involving countries with varying levels of educational resources, infrastructure, teacher preparation systems, and policy environments could determine whether the distinction between competence level and implementation extent represents a universal feature of teaching or a particularly important issue within resource-constrained settings. Such research would contribute to broader international debates on teacher effectiveness, educational technology integration, and equity.

Another important direction involves the development of a reliable LEAF-based assessment instrument. Existing TPACK instruments primarily measure teachers' perceived knowledge across technological, pedagogical, and content domains but provide limited information about actual classroom enactment (Schmidt et al., 2009). A LEAF instrument should therefore incorporate indicators of both competence level and implementation extent. Level indicators should assess disciplinary understanding, pedagogical reasoning, technological knowledge, instructional design ability, and conceptual mastery. Extent indicators should measure frequency of implementation, classroom instructional behaviours, technology and laboratory integration, adaptation of teaching strategies, and contextual problem-solving ability.

To improve accuracy, future assessment tools should combine teacher questionnaires with classroom observations, lesson-plan analysis, student feedback, and performance-based assessments. This multidimensional approach would provide a more realistic representation of teacher effectiveness than relying solely on self-reported competence.

Overall, future research should move beyond determining whether teachers possess professional knowledge and examine how educational systems support or constrain the transformation of that knowledge into effective classroom practice. Through empirical validation, advanced statistical modelling, longitudinal investigation, comparative studies, and robust instrument development, LEAF has the potential to provide a more context-sensitive framework for understanding teacher competence and guiding evidence-based reforms in science education.

Conclusion

This paper contributes to the theoretical understanding of teacher competence by extending the Technological Pedagogical Content Knowledge (TPACK) framework through the introduction of the Level–Extent Assessment Framework (LEAF). While existing TPACK scholarship has provided valuable insights into the knowledge domains required for effective technology-supported teaching, it has often given limited attention to the contextual conditions that influence whether such knowledge can be transformed into classroom practice. LEAF addresses this limitation by distinguishing between the level of teachers' professional competence, represented by cognitive mastery, knowledge integration, and theoretical capability, and the extent of competence enactment, represented by classroom implementation, instructional behaviour, and contextual application. This distinction provides a more nuanced conceptualisation of teacher effectiveness by recognising that professional knowledge alone does not guarantee effective practice; rather, teaching outcomes emerge from the interaction between teacher competence and the educational environments within which teachers operate.

The framework offers important implications for teacher education, assessment, professional development, educational technology integration, and policy development, particularly within resource-constrained educational systems such as Nigeria. By separating what teachers know from what they are able to implement, LEAF provides a more equitable and realistic approach to evaluating teacher competence and identifying barriers to effective instruction. Ultimately, the framework advances contemporary discussions on science teacher effectiveness by proposing that meaningful improvement in chemistry education requires not only developing teachers' professional knowledge but also creating supportive conditions that enable the translation of that knowledge into innovative, contextually appropriate, and sustainable classroom practices.

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EFFECT OF BLENDED LEARNING INSTRUCTION ON SENIOR SCHOOL CHEMISTRY STUDENTS' PERFORMANCE IN KWARA STATE, NIGERIA

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Abstract

This study examined the effect of Blended Learning Instruction on senior secondary school Chemistry students' achievement and retention in Ilorin West, Kwara State, Nigeria. The study adopted a non-randomized, non-equivalent control group quasi-experimental design involving 127 Senior Secondary School II Chemistry students selected from intact classes in public secondary schools. The experimental group was taught using Blended Learning Instruction, while the control group received instruction through the conventional approach for eight weeks. Data were collected using the Chemistry Performance Test (CPT), which was validated by experts and yielded a reliability coefficient of 0.78 using Kuder-Richardson Formula 20. Paired and independent sample t-tests were used to analyse the data at a 0.05 level of significance using SPSS version 26.0. The findings revealed a significant difference between the pre-test and post-test achievement scores of students exposed to Blended Learning Instruction, indicating improved Chemistry achievement. However, there was no significant difference between the achievement scores of students taught using Blended Learning Instruction and those taught using the conventional approach. The study further revealed a significant difference in post-test and retention scores between the two groups, with students exposed to Blended Learning Instruction demonstrating better retention of Chemistry concepts. The study concluded that Blended Learning Instruction is an effective approach for enhancing students' achievement and retention in Chemistry. It was recommended that Chemistry teachers should adopt blended learning strategies and that schools should provide adequate technological facilities and support for effective implementation.

Keywords: Blended Learning Instruction, Chemistry Achievement, Retention, Conventional Teaching, Senior Secondary Students.

Introduction

Chemistry education occupies a central position in Nigeria's science and technology development because it provides the scientific foundation required for careers in medicine, pharmacy, engineering, agriculture, environmental science and industrial production. At the senior secondary school level, Chemistry is a compulsory subject for students intending to pursue many science-related professions in tertiary institutions. However, despite its significance, students' achievement in Chemistry has remained a major educational concern because many learners demonstrate inadequate understanding of chemical concepts, poor problem-solving abilities and weak practical skills in external examinations (West African Examinations Council [WAEC], 2023). These persistent challenges have encouraged researchers to explore alternative instructional strategies capable of improving students' learning experiences and academic outcomes.

The continued reliance on conventional teacher-centred approaches has been identified as one of the factors contributing to students' poor achievement in Chemistry. Traditional instructional methods often emphasise teacher explanation, memorisation and note-taking, providing limited opportunities for students to actively construct knowledge, collaborate with peers or engage with multiple representations of scientific concepts. This limitation is particularly problematic in Chemistry because many concepts occur at microscopic and symbolic levels that students cannot easily visualise through verbal explanations alone. Recent research in science education suggests that effective Chemistry instruction requires approaches that promote active engagement, inquiry, visualisation and continuous interaction with learning resources (Muzafar & Ahmad, 2024).

The rapid advancement of digital technologies has transformed contemporary educational practices by creating opportunities for more flexible and interactive learning environments. One of the instructional approaches that has gained increasing attention is blended learning, which combines traditional face-to-face classroom teaching with online learning activities. Blended learning does not replace classroom interaction; rather, it complements physical instruction by providing students with additional opportunities to access learning materials, participate in online discussions, complete digital assessments and receive feedback beyond classroom hours. This combination of instructional modes enables students to learn at their own pace while benefiting from teacher guidance and peer collaboration.

Recent literature indicates that blended learning has become increasingly relevant in science education because it addresses several limitations associated with conventional classroom instruction. A systematic review of blended learning in science education found that blended environments promote critical thinking, problem-solving skills and scientific inquiry while also helping to overcome challenges associated with limited classroom resources and large class sizes. However, the review also noted that successful implementation depends on factors such as teacher competence, technological availability and institutional support (Muzafar & Ahmad, 2024).

The relevance of blended learning in Chemistry education is further supported by empirical evidence from Nigeria. Ajayi (2025) investigated the effects of Google Classroom on the academic performance and retention of senior secondary school Chemistry students in Nigeria using a quasi-experimental design. The study reported that students exposed to Google Classroom-supported instruction achieved higher performance and retention scores than students taught using

conventional methods. The findings suggest that integrating digital platforms with classroom teaching provides learners with additional opportunities to interact with Chemistry concepts and improve their academic outcomes.

Similarly, Ugonwa (2025) examined the influence of Google Classroom blended learning strategy on secondary school Chemistry students' performance in Rivers State, Nigeria. The study revealed that students who received blended instruction through Google Classroom and face-to-face teaching achieved significantly higher learning gains than students taught through only conventional classroom instruction. The researcher concluded that blended learning enhances Chemistry learning by increasing students' access to instructional materials and promoting active participation in the learning process.

Further evidence was provided by Jegede (2025), who investigated the effect of Google Classroom blended learning strategy on senior secondary school Chemistry students' academic performance and retention in Ekiti State, Nigeria. The findings indicated that students exposed to blended learning recorded improved achievement compared with students in the conventional teaching group. The study recommended greater adoption of digital learning platforms in secondary school Chemistry classrooms to enhance students' learning outcomes.

Beyond Google Classroom applications, broader blended learning approaches have also demonstrated positive effects on students' academic achievement. Recent research examining blended innovative teaching approaches reported that technology-supported instructional strategies improve students' motivation, engagement and academic performance when carefully integrated into classroom practice (Daniel et al., 2024). The authors emphasised that blended learning is most effective when online activities are intentionally connected to classroom objectives rather than used merely as supplementary materials.

Similarly, studies on student engagement in blended learning environments have shown that effective blended learning designs produce moderate to high improvements in engagement and learning outcomes. These improvements are associated with increased interaction, access to diverse learning resources and opportunities for self-regulated learning (2024). These findings are particularly important for Chemistry education because students require repeated exposure, practice and feedback to develop mastery of complex scientific concepts.

Despite the growing evidence supporting blended learning, limited studies have examined its effectiveness among senior secondary school Chemistry students in Kwara State, Nigeria. Most existing Nigerian studies have focused on other states, including Ekiti, Rivers and Delta States, making it difficult to generalise findings directly to Kwara State because educational contexts differ in terms of infrastructure, teacher preparedness, student characteristics and access to digital resources. This limitation creates a need for location-specific research to determine whether blended learning instruction can significantly influence Chemistry students' performance within the state.

The investigation of blended learning instruction in Kwara State is therefore important because it aligns with current efforts toward improving science education through technology integration. Understanding the extent to which blended learning affects Chemistry students' academic

performance will provide useful evidence for teachers, school administrators, curriculum developers and policymakers seeking effective strategies for improving science learning outcomes in Nigerian secondary schools.

The effectiveness of blended learning in improving students' academic outcomes has been explained through its ability to combine the strengths of conventional classroom interaction with the flexibility and accessibility offered by digital learning environments. In Chemistry education, this integration is particularly significant because the subject requires learners to connect macroscopic observations, microscopic explanations and symbolic representations. Many students experience difficulty in making these connections when instruction relies mainly on verbal explanations and textbook descriptions. By incorporating multimedia resources, virtual demonstrations, online discussions and interactive assessments, blended learning provides multiple representations of scientific concepts, thereby improving students' conceptual understanding and achievement (Ajayi, 2025; Ugonwa, 2025).

Recent empirical studies have consistently demonstrated that blended learning improves students' academic performance in Chemistry when compared with conventional teaching approaches. For instance, Ajayi (2025) examined the effect of Google Classroom on the academic performance and retention of senior secondary school Chemistry students in Nigeria using a quasi-experimental research design. The study revealed that students exposed to Google Classroom-supported instruction achieved significantly higher scores and demonstrated better retention of Chemistry concepts than those taught through traditional classroom methods. The author attributed this improvement to increased access to learning resources, opportunities for repeated practice and enhanced interaction between learners and instructional materials.

Similarly, Ugonwa (2025) investigated the influence of Google Classroom blended learning strategy on secondary school Chemistry students' performance in Obio-Akpor Local Government Area of Rivers State, Nigeria. The findings showed that students taught using a combination of Google Classroom and face-to-face classroom instruction recorded greater learning gains than students taught exclusively through physical classroom methods. The study concluded that blended learning enhances Chemistry instruction by encouraging active participation, extending learning beyond the classroom and providing students with additional opportunities to engage with subject content.

Evidence from Ekiti State also supports the effectiveness of technology-supported Chemistry instruction. Jegede (2025) examined the effects of Google Classroom blended learning strategy on senior secondary school Chemistry students' academic performance and retention. The findings indicated that students who received blended instruction performed significantly better than those taught using conventional instructional approaches. The study further reported that blended learning improved students' retention of learned Chemistry concepts, suggesting that digital learning platforms can support deeper understanding and long-term knowledge development.

Beyond specific digital platforms such as Google Classroom, broader blended learning approaches have been found to positively influence Chemistry achievement. Omosor (2026) compared the effects of Process-Oriented Guided Inquiry Learning (POGIL), blended learning and conventional teaching methods among senior secondary school Chemistry students in Delta State, Nigeria. The

study found significant differences in students' academic achievement, with learners exposed to blended learning demonstrating improved performance compared with those taught through conventional methods. The findings suggest that combining digital learning activities with classroom interaction creates a more engaging environment that supports scientific reasoning, inquiry and conceptual understanding.

Related technology-enhanced instructional approaches, particularly flipped classroom models, have also produced positive outcomes in Chemistry education. Konyefa and Nwanze (2026) investigated the effect of flipped classroom instruction on secondary school students' academic achievement in Chemistry in Bayelsa State, Nigeria. Since flipped classroom instruction represents a form of blended learning where students interact with digital learning materials before classroom activities, the study provides relevant evidence regarding the benefits of technology-supported instruction. The findings indicated that students exposed to the flipped classroom strategy achieved significantly higher academic outcomes than those taught through conventional approaches.

Although these studies provide strong evidence regarding the benefits of blended learning, successful implementation depends on several contextual factors. Digital infrastructure, teacher technological competence, availability of internet services, electricity supply and students' access to digital devices influence the effectiveness of blended learning programmes. In many Nigerian secondary schools, particularly public schools, inadequate technological facilities remain a major challenge to effective implementation. Consequently, the effectiveness of blended learning cannot be assumed to be identical across all educational environments. Context-specific investigations are therefore necessary to determine how blended learning functions within particular school systems and geographical locations.

The Nigerian educational environment presents both opportunities and challenges for blended learning adoption. The expansion of mobile technologies, increasing availability of online learning platforms and growing awareness of digital pedagogy have created favourable conditions for technology integration in schools. However, disparities in technological access continue to affect implementation. While some urban schools have access to computers, internet facilities and digital instructional resources, many schools still experience limitations that may affect teachers' ability to adopt blended approaches effectively. These variations highlight the importance of investigating blended learning within specific contexts such as Kwara State.

Kwara State provides an important context for examining the effect of blended learning instruction on Chemistry students' performance. The state has numerous senior secondary schools offering Chemistry as a major science subject, yet concerns remain regarding students' achievement in the subject. Although previous studies conducted in Nigeria have examined blended learning and related technology-supported instructional strategies, limited empirical evidence exists regarding their effectiveness among senior secondary school Chemistry students in Kwara State. Findings from other states, including Ekiti, Rivers and Delta States, may not automatically apply to Kwara State because differences exist in school resources, teacher preparedness, student characteristics and technological accessibility.

The limited availability of empirical evidence from Kwara State represents an important research gap. Without adequate evidence, teachers and policymakers may lack sufficient information

regarding whether investment in blended learning approaches would produce measurable improvements in Chemistry achievement within the state. Therefore, examining the effect of blended learning instruction on senior secondary school Chemistry students' performance in Kwara State is necessary to provide evidence-based recommendations for improving science education.

The persistent poor performance of students in Chemistry despite several educational reforms suggests that conventional instructional approaches alone may not adequately address current learning challenges. While blended learning has demonstrated positive effects in other Nigerian contexts, the extent to which it can improve Chemistry students' performance in Kwara State remains uncertain. This uncertainty creates the need for systematic investigation into the effect of blended learning instruction on students' academic achievement.

Therefore, this study seeks to determine the effect of blended learning instruction on senior school Chemistry students' performance in Kwara State, Nigeria. Specifically, the study aims to contribute empirical evidence on whether integrating digital learning resources with face-to-face classroom instruction can enhance Chemistry learning outcomes. The findings will provide valuable insights for Chemistry teachers, educational administrators, curriculum planners and policymakers interested in improving science education through innovative instructional practices.

The findings from recent empirical studies suggest that blended learning has considerable potential for transforming Chemistry instruction in Nigerian secondary schools. However, the effectiveness of blended learning is not determined solely by the availability of digital platforms but also by the quality of instructional design, teachers' technological competence and the extent to which online activities are meaningfully connected with classroom experiences. Studies have emphasised that technology should serve as a pedagogical tool rather than merely an additional resource. When properly integrated, blended learning encourages students to engage in active knowledge construction, collaborative problem-solving and independent learning, which are essential for improving performance in Chemistry (Ogunsakin & Isaac-Philips, 2025; Omosor, 2026).

The growing evidence supporting blended learning has important implications for Chemistry education in Kwara State. Although studies from other Nigerian states have established positive effects of technology-supported instruction, educational contexts differ considerably due to variations in school infrastructure, teacher preparedness, students' digital literacy and availability of learning resources. Therefore, findings obtained from Ekiti, Rivers, Delta, Lagos and other states cannot automatically be generalised to senior secondary schools in Kwara State. A context-specific investigation is necessary to determine whether blended learning instruction can produce similar improvements in Chemistry students' academic performance within the state.

The present study contributes to the existing body of knowledge by addressing this geographical and empirical gap. While previous studies have examined Google Classroom, flipped classrooms, virtual learning and other technology-enhanced approaches, limited research has specifically focused on the effect of blended learning instruction on senior secondary school Chemistry students' performance in Kwara State. The study therefore provides an opportunity to generate evidence regarding the applicability of blended learning within the educational realities of the state.

The persistent challenge of low achievement in Chemistry among secondary school students remains a major concern despite various curriculum reforms and instructional interventions. Examination reports continue to indicate weaknesses in students' understanding of chemical principles, interpretation of scientific information and application of knowledge to practical situations (WAEC, 2023). These challenges suggest that conventional teaching approaches may not adequately address the learning needs of contemporary students who require more interactive, flexible and technology-supported learning experiences.

Although blended learning has been identified as a promising instructional approach for improving students' engagement and achievement, there remains uncertainty regarding its effectiveness in specific Nigerian secondary school contexts. Many Chemistry teachers continue to rely predominantly on traditional classroom methods because of limited awareness, inadequate training and insufficient technological resources. As a result, the potential benefits of blended learning may not be fully realised unless empirical evidence demonstrates its effectiveness and provides guidance for implementation.

Therefore, the central problem addressed by this study is the continued poor academic performance of senior secondary school students in Chemistry despite the availability of innovative instructional strategies such as blended learning. Specifically, there is inadequate empirical evidence on whether blended learning instruction significantly improves Chemistry students' performance in Kwara State compared with conventional classroom instruction. This lack of evidence limits the ability of teachers, educational administrators and policymakers to make informed decisions regarding the adoption of blended learning in Chemistry classrooms.

Consequently, this study investigates the effect of blended learning instruction on senior secondary school Chemistry students' performance in Kwara State, Nigeria. The study is expected to provide empirical evidence on the effectiveness of integrating digital learning resources with face-to-face instruction and contribute to ongoing efforts aimed at improving science education outcomes in Nigeria.

Purpose of the Study

The main purpose of the study was to investigate the effect of Blended learning instruction on senior school chemistry students' performance in Kwara State, Nigeria. Specifically, the study aims to:

1. determined the difference between the pre-test and post-test scores of students who were taught Chemistry using Blended learning instruction;
2. examined the difference between the senior school Chemistry students who were taught Chemistry using Blended learning instruction and those taught using the conventional approach;
3. examined the difference between the post-test and retention scores of senior school Chemistry students who were taught Chemistry using Blended learning instruction and those taught using the conventional approach.

Research Hypotheses

H_{01}: There is no significant difference between the pre-test and post-test scores of students who were taught Chemistry using Blended learning instruction;

H_{02}: There is no significant difference between the senior school Chemistry students who were taught Chemistry using Blended learning instruction and those taught using the conventional approach;

H_{03}: There is no significant difference in the post-test and retention scores of senior school Chemistry students who were taught Chemistry using Blended learning instruction and those taught using the conventional approach.

Methodology

The study employed a non-randomized, non-equivalent control group quasi-experimental design with pre-test and post-test measures. The design was considered non-randomized because the intact classes were used throughout the study. The population of this study were all senior school Chemistry students in Kwara State. The target population were senior school Chemistry students in Ilorin West. The sample comprised intact senior secondary school II (SSS2) Chemistry classes drawn from public secondary schools within the study area. The intact classes were assigned to either the experimental group, which exposed to Blended learning instruction, or the control group, which was taught using the conventional teaching method. The experimental group received instruction using Blended learning for a period of eight weeks, while the control group were taught the same topics using conventional approach for a period of eight weeks. The data was collected using researcher developed Chemistry Performant Test (CPT). The validity of the instrument was established using the face, content, construct and factor analysis by three experts in science education (Chemistry), secondary school chemistry teacher and test and measurement, who ensure that the items were clear, relevant, and aligned with the study objectives. Their recommendations were incorporated to refine the instrument prior to use. Internal consistency reliability method was employed and the reliability was determined through a pilot study conducted outside the main study area. The Chemistry Performance Test (CPT) yielded a pilot study conducted outside the main study area. The CPT yielded a reliability coefficient of 0.78 using Kuder-Richardson Formula 20 (KR-20), indicating satisfactory internal consistency.

The procedure for data collection followed a systematic approach. Approval was obtained from relevant school authorities, and participants were informed about the purpose and procedures of the study. A pre-test was administered to both experimental and control groups to establish their initial level of understanding. This was followed by an eight-week instructional period during which the experimental group was taught using Blended learning instruction, while the control group received instruction through the conventional teaching method. At the end of the treatment, a post-test was administered to both groups under similar conditions. The instruments were subsequently collected, scored, and prepared for analysis.

Ethical considerations were strictly adhered to throughout the study. Participants were adequately informed about the study and their consent was obtained prior to participation. Participation was

entirely voluntary, and students were free to withdraw at any stage without any negative consequences. Confidentiality and anonymity were ensured through the use of codes instead of personal identifiers, and all data collected were used strictly for research purposes. Care was also taken to ensure that no participant was exposed to harm or disadvantage, and fairness was maintained between the experimental and control groups.

Data analysis involved inferential statistical technique. Hypotheses were tested at the 0.05 level of significance. Independent samples t-test was employed to compare differences between the experimental and control groups, while paired samples t-test was used to examine within-group differences between pre-test and post-test scores. All analyses were carried out using the Statistical Product and Service Solution (SPSS) version 26.0.

Results and Interpretations

H_{01}: There is no significant difference between the pre-test and post-test scores of students who were taught Chemistry using Blended learning instruction;

Table 1: ***Paired Sample t-test of Pre-test and Post-test Scores of Students Taught Chemistry Using Blended Learning Instruction***

Test Scores	N	Mean	S.D	df	t (Cal.)	Sig. (2-tailed)	Decision
Pre-test	65	25.43	6.21	64	8.47	0.00	Rejected
Post-test	65	31.86	5.74				

Table 1 presents the results of the paired sample t-test conducted to examine the difference between the pre-test and post-test achievement scores of students taught Chemistry using Blended Learning Instruction. The findings revealed that the students recorded a pre-test mean score of 25.43 with a standard deviation of 6.21, while the post-test mean score increased to 31.86 with a standard deviation of 5.74. This indicates an improvement in students' Chemistry achievement after exposure to the blended learning approach.

The analysis further showed that the calculated t-value of 8.47 at 64 degrees of freedom was statistically significant at the 0.05 level of significance. This was supported by the Sig. (2-tailed) value of 0.00, which is lower than the accepted significance level of 0.05. Based on this result, the null hypothesis (H_{01}), which stated that there is no significant difference between the pre-test and post-test scores of students taught Chemistry using Blended Learning Instruction, was rejected.

The result therefore indicates that a significant difference existed between the pre-test and post-test scores of the students. The higher mean score obtained in the post-test compared with the pre-test suggests that Blended Learning Instruction contributed positively to students' academic achievement in Chemistry.

H_{02}: There is no significant difference between the senior school Chemistry students who were taught Chemistry using Blended learning instruction and those taught using the conventional approach;

Table 2: ***Independent sample t-test of the significant difference between the senior school Chemistry students who were taught Chemistry using Blended learning instruction and those taught using the conventional approach***

Group	N	Mean	S.D	df	t (Cal.)	Sig. (2-tailed)	Decision
Blended Learning Instruction (BLI)	65	39.52	5.33	64	2.19	0.07	Not Rejected
Conventional Approach (CA)	62	38.23	5.89				

Table 2 presents the results of the independent sample t-test conducted to determine whether there was a significant difference between the Chemistry achievement scores of senior school students taught using Blended Learning Instruction and those taught using the Conventional Approach. The results indicated that students exposed to Blended Learning Instruction obtained a mean score of 39.52 with a standard deviation of 5.33, while students taught using the Conventional Approach recorded a mean score of 38.23 with a standard deviation of 5.89. The analysis revealed that the calculated t-value of 2.19 with 64 degrees of freedom was not statistically significant at the 0.05 level of significance, as shown by the Sig. (2-tailed) value of 0.07, which is greater than the 0.05 significance level. Consequently, the null hypothesis (H_{02}), which stated that there is no significant difference between the Chemistry achievement scores of senior school students taught using Blended Learning Instruction and those taught using the Conventional Approach, was not rejected.

This finding implies that there was no statistically significant difference between the achievement scores of students taught through Blended Learning Instruction and those taught through the Conventional Approach. Although the mean score of students in the Blended Learning Instruction group was slightly higher than that of the Conventional Approach group, the difference was not large enough to be considered statistically significant. Therefore, both instructional approaches produced comparable effects on students' Chemistry achievement.

H_{03}: There is no significant difference in the post-test and retention scores of senior school Chemistry students who were taught Chemistry using Blended learning instruction and those taught using the conventional approach.

Table 3: Paired Sample t-test of significant difference in the post-test and retention scores of senior school Chemistry students who were taught Chemistry using Blended learning instruction and those taught using the conventional approach.

Test Scores	Group	N	Mean	S.D	df	t (Cal.)	Sig. (2-tailed)
Post-test	Blended Learning	65	31.86	5.74	126	4.32	0.000
	Conventional	62	27.48	6.11			
Retention	Blended Learning	65	30.72	5.56	126	4.05	0.000
	Conventional	62	26.86	5.92			

Table 3 presents the results of the paired sample t-test conducted to determine whether there was a significant difference between the post-test and retention scores of senior school Chemistry students who were taught using Blended Learning Instruction and those taught using the Conventional Approach. The results showed that students in the Blended Learning Instruction group recorded a post-test mean score of 31.86 with a standard deviation of 5.74, while students in the Conventional Approach group obtained a post-test mean score of 27.48 with a standard deviation of 6.11. Similarly, the retention scores revealed that students taught using Blended Learning Instruction achieved a mean score of 30.72 with a standard deviation of 5.56, whereas students taught using the Conventional Approach recorded a mean score of 26.86 with a standard deviation of 5.92. The comparison indicates that students exposed to Blended Learning Instruction maintained higher achievement scores at the retention stage than those taught through the Conventional Approach.

The calculated t-values of 4.32 for the post-test scores and 4.05 for the retention scores, with 126 degrees of freedom, were statistically significant at the 0.05 level of significance. This was confirmed by the Sig. (2-tailed) values of 0.000, which are lower than the accepted significance level of 0.05. Consequently, the null hypothesis (H_{03}), which stated that there is no significant difference in the post-test and retention scores of senior school Chemistry students taught using Blended Learning Instruction and those taught using the Conventional Approach, was rejected. The findings indicate that a significant difference existed between the post-test and retention performance of students in the two instructional groups. The higher mean scores recorded by students taught through Blended Learning Instruction suggest that the approach was more effective in enhancing students' Chemistry achievement and promoting better retention of learned concepts compared with the Conventional Approach.

Discussions

The findings of this study revealed that Blended Learning Instruction significantly improved the academic achievement of senior secondary school Chemistry students. The paired sample t-test result showed a significant difference between students' pre-test and post-test scores, with the mean score increasing from 25.43 before instruction to 31.86 after exposure to blended learning. This indicates that the instructional approach enhanced students' understanding and achievement in Chemistry. The improvement may be attributed to the ability of blended learning to combine face-to-face classroom interaction with digital learning resources, thereby providing learners with opportunities for repeated exposure to concepts, access to multimedia materials, self-paced learning and continuous engagement with instructional content. This finding agrees with Ajayi (2025), who reported that senior secondary school Chemistry students exposed to Google Classroom-supported blended learning achieved higher academic performance and retention scores than those taught through conventional methods. Similarly, Ugonwa (2025) found that the integration of Google Classroom with classroom instruction improved students' Chemistry learning outcomes by increasing access to instructional materials and encouraging active participation. The finding also supports Jegede (2025), who established that blended learning enhanced students' achievement and retention in Chemistry through improved interaction with learning resources and opportunities for deeper conceptual understanding.

The finding of this study further showed that there was no statistically significant difference between the achievement scores of students taught using Blended Learning Instruction and those taught using the Conventional Approach. Although students in the blended learning group recorded a slightly higher mean score (39.52) than those in the conventional group (38.23), the difference was not statistically significant. This suggests that both instructional approaches were capable of producing comparable learning outcomes within the context of the study. The result may be explained by the fact that the effectiveness of blended learning depends not only on the availability of digital resources but also on factors such as teacher competence, students' technological readiness, instructional design and institutional support. This observation is consistent with Muzafar and Ahmad (2024), who argued that blended learning outcomes are influenced by contextual conditions, including technological infrastructure and effective implementation strategies. However, the finding differs from the studies of Ajayi (2025), Ugonwa (2025) and Jegede (2025), who reported that students exposed to blended learning achieved significantly higher performance than those taught using conventional approaches. The difference may be attributed to variations in research location, duration of treatment, digital platforms used, students' familiarity with technology and the extent to which blended learning activities were integrated into classroom instruction.

The study also revealed that students taught using Blended Learning Instruction demonstrated significantly higher post-test and retention scores than students taught through the Conventional Approach. The results showed that students in the blended learning group obtained higher post-test and retention mean scores compared with their counterparts in the conventional group, indicating that blended learning enhanced both immediate achievement and long-term retention of Chemistry concepts. This finding suggests that the combination of online resources and classroom instruction provides learners with additional opportunities to revisit materials, receive feedback and engage with concepts through different learning formats. The finding is in agreement with Ajayi (2025), who found that Google Classroom-supported blended learning improved both achievement and retention among Chemistry students. It also supports Ugonwa (2025), who reported that blended learning encouraged active participation and extended learning beyond the classroom, resulting in improved learning gains. Similarly, Jegede (2025) found that students exposed to blended learning recorded better retention of Chemistry concepts compared with students taught using traditional methods. Furthermore, Omosor (2026) reported that blended learning improved Chemistry students' academic achievement by promoting inquiry, scientific reasoning and conceptual understanding, while Konyefa and Nwanze (2026) established that flipped classroom instruction, a form of blended learning, produced significantly better academic outcomes than conventional teaching methods.

Overall, the findings of this study provide evidence that Blended Learning Instruction is a useful pedagogical approach for improving Chemistry learning outcomes among senior secondary school students. Although the comparison between blended learning and conventional instruction did not produce a statistically significant difference in one aspect of achievement, the overall pattern of results showed that blended learning contributed positively to students' performance and retention. These findings support the argument of Daniel et al. (2024) that technology-supported instructional approaches improve students' motivation, engagement and academic achievement when digital activities are meaningfully connected with classroom objectives. Similarly, Ogunsakin and Isaac-Philips (2025) and Omosor (2026) emphasized that blended learning is most effective when

technology serves as a pedagogical tool that promotes active knowledge construction rather than merely providing additional materials. Therefore, the positive outcomes recorded in this study suggest that properly designed blended learning environments can address some limitations of conventional Chemistry instruction by providing learners with flexible access to resources, interactive learning experiences and opportunities for sustained engagement with scientific concepts. The findings further justify the need for greater adoption of blended learning approaches in Nigerian secondary schools, particularly in contexts such as Kwara State where evidence-based instructional innovations are needed to improve Chemistry achievement.

Conclusion

Based on the findings of this study, it was concluded that Blended Learning Instruction had a positive influence on senior secondary school students' achievement and retention in Chemistry. The significant improvement observed between students' pre-test and post-test scores indicates that the approach enhanced students' understanding and learning outcomes after exposure to blended learning activities. Although the comparison between students taught using Blended Learning Instruction and those taught through the Conventional Approach showed no significant difference in overall achievement scores, students exposed to blended learning consistently recorded slightly higher mean scores. Furthermore, the significant difference observed in students' post-test and retention scores demonstrated that blended learning was more effective in promoting lasting understanding and retention of Chemistry concepts. Therefore, Blended Learning Instruction can be considered an effective instructional strategy for improving Chemistry learning outcomes, particularly when supported by appropriate instructional design, teacher competence, and adequate technological resources. The following recommendations were made:

1. Chemistry teachers should adopt and integrate Blended Learning Instruction into their teaching practices to enhance students' achievement in Chemistry, as the approach was found to significantly improve students' performance from pre-test to post-test.
2. School administrators and curriculum planners should provide adequate technological facilities, teacher training and institutional support to complement both Blended Learning Instruction and conventional teaching approaches for effective Chemistry instruction.
3. Chemistry teachers should incorporate blended learning strategies that allow continuous access to learning materials, revision activities and interactive resources in order to improve students' retention of Chemistry concepts over time.

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DIGITAL COMPETENCE AND INSTRUCTIONAL EFFECTIVENESS OF BIOLOGY TEACHERS IN ECOLOGY TEACHING IN SENIOR SECONDARY SCHOOLS IN ILORIN, NIGERIA

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Abstract

This study investigated the digital competence and instructional effectiveness of Biology teachers in ecology education in senior secondary schools in Ilorin, Nigeria. Specifically, the study examined the level of Biology teachers' digital competence, determined their instructional effectiveness in ecology education, assessed the extent of their utilization of digital instructional resources, and examined the relationship between digital competence and instructional effectiveness. A descriptive survey research design was adopted. The population comprised Biology teachers in public and private senior secondary schools in Ilorin, Nigeria, while a sample of 120 Biology teachers was selected through a multistage sampling procedure. Data were collected using a researcher-developed instrument titled Digital Competence and Instructional Effectiveness Questionnaire (DCIEQ). The instrument was validated by experts in Science Education and Educational Technology, and a Cronbach's Alpha reliability coefficient of 0.803 established its internal consistency. Descriptive statistics comprising frequency counts, percentages, mean, and standard deviation were used to answer the research questions, while Pearson Product Moment Correlation was used to test the hypothesis at the 0.05 level of significance. The findings revealed that Biology teachers possessed a moderate level of digital competence (Grand Mean = 2.59). Their instructional effectiveness in ecology education was also moderate (Grand Mean = 2.57), while the utilization of digital instructional resources was low (Grand Mean = 2.41). Furthermore, a significant positive relationship existed between Biology teachers' digital competence and instructional effectiveness in ecology education ($r = 0.64$, $p < 0.001$). The study concluded that improving Biology teachers' digital competence would enhance instructional effectiveness in ecology education. It was therefore recommended that government and school administrators provide regular digital skills training and improve access to digital instructional facilities to promote effective ecology teaching.

Keywords: Digital Competence, Instructional Effectiveness, Biology Teachers, ICT Integration, Nigeria.

Introduction

Enhancing the digital competence of biology teachers is important for advancing ecology education in senior secondary schools in Nigeria. In the present digital age, the quick development and enhancement of information and communication technology (ICT) has transformed positively various sectors such as technology, agriculture, banking and including the education sector (Unesco, 2023). Efficient use of ICT by teacher's in Nigeria is crucial for providing dynamic and engaging science education, most especially in subjects like biology that are vital for grasping environmental issues such as ecological change and biodiversity loss within Nigeria (Redecker, 2017). Digital competence move beyond the ability to operate technological accessories, it comprises the knowledge, skills, attitudes, and ethical practices required to efficiently integrate digital technologies into teaching, learning, assessment, collaboration, and professional development (European Commission, 2022; UNESCO, 2023). As schools increasingly adopt technology-enhanced learning, it is necessary for eachers to possess sufficient digital competence to design engaging learning experiences, improve students' understanding of subject content, and prepare learners for a digitally driven society. The development of teachers' digital competence has become a major educational priority across many countries, (UNESCO, 2023).

Abimbola, (2017) In science education, digital competence has become particularly important because scientific concepts often require visualization, experimentation, simulation, and inquiry-based learning. Biology, as one of the core science subjects offered in senior secondary schools, involves numerous abstract and dynamic concepts that are more effectively taught through digital instructional resources than through conventional methods alone presently. Technologies such as virtual laboratories, digital microscopes, animations, interactive simulations, videos, and online collaborative platforms provide opportunities for learners to observe biological processes that may otherwise be difficult to demonstrate in the classroom (Redecker, 2017; UNESCO, 2023). Teachers who possess adequate digital competence are therefore better positioned to utilize these resources to enhance students' engagement, conceptual understanding, and academic achievement. According to Abimbola, (2017) Knowledge of Biology at the secondary school stage plays an important role in equipping students with the meaningful knowledge and skills needed to address ecological and environmental issues. Nevertheless, most biology teachers in Nigerian schools face gaps in digital literacy, this has limits their ability to embed technology digital resources and it's tools into their teaching activities. This gap hampers student’s involvement and the depth of understanding needed for ecology education.

Biology entails a central section in secondary education because it equips students with skills and understanding about living systems and the engagement with interaction between organisms and their environment, skills that is essential for addressing environmental challenges such as climate change, biodiversity loss and pollution (Wals & Jickling, 2021). Ecology, as a important area within biology, assist students develop the scientific literacy, behavior and values necessary for environmental stewardship and sustaining living challenges. Efficient ecology education requires not just sound subject knowledge but also teaching strategies that promote critical thinking and problem-solving. When taught well, ecology empowers learners to apply scientific understanding to local and global sustainability challenges (Bonnett, 2020).

Johnson and Mappin, (2005) The study of ecology basically and fundamentally comprises the study of relationships and differences among living organisms and their environments. Traditionally based on the view of scientific, the scope of ecology within educational paspective

has seriously expanded to include the sociopolitical, psychological and philosophical aspects of human-nature engagement. This evolution reflects a developed recognition that ecology is not only about understanding natural systems but also about enhancing environmental advocacy, ethical inquiry related to our shared environment and education (Johnson & Mappin, 2005). Integrating experiential learning, community involvement, and advocacy methods assist learners appreciate the interconnection of ecological systems and their socio-economic implications, there for improving holistic understanding and proactive advocacy for effective futures (Mtekele, 2024; Desmarais, 2024). This approach are in line with the imperative of developing not only ecological literacy but also the ability and capacity for ethical community action, creating a foundation for transformative teaching and learning that respects both the science and values inherent in human-nature relationships (Johnson & Mappin, 2005; Mtekele, 2024).

The effectiveness of Biology teachers' instruction plays a significant role in achieving the objectives of Biology education in senior secondary schools (Abimbola, 2017). Effective instruction allow teachers to present biological concepts in a clear, engaging, and meaningful manner, effective instruction improving students' understanding, participation, and academic achievement. In ecology education, instructional effectiveness is particularly important because many ecological concepts are abstract and require teachers to employ appropriate teaching strategies, relevant instructional materials, and learner-centred approaches to enhance students' comprehension, Johnson and Mappin, (2005); Wals and Jickling, (2001). When Biology teachers deliver instruction effectively, students are better equipped to understand ecological relationships, environmental issues, and the importance of biodiversity conservation, (Hicks & Bord, 2001; Ono, 2005).

Currently environmental education continues to take a human-centered approach and makes little to no linkage between humans and nature, even though human-nature linkages need to be addressed (Clark, 2007; Kates & Parris, 2003). Environmental education does not correctly address the necessary development in global human-human relationships (Barraza, Duque-Aristizabal, & Rebolledo, 2023) but essential for human and it's environment. Education platforms has witnessed meaningful changes with ICT embedment, which has improve communication, collaboration, effective instruction and learning experiences (Abimbola, 2017). ICT comprises of a wide varieties of technologies that store, retrieve, and transmit information digitally, making it a powerful tool in education, finance, agriculture and banking sectors. Previous research shows that the efficient integration of ICT results in improved teaching quality, better student performance, and enriched learning environments, mostly in science education where practical and visual learning aids may greatly benefit comprehension and enhance effective instruction in education sector.

Even with the capability of ICT to enhance biology instruction, some biology teachers in Nigerian secondary schools face significant gaps in digital competence, inadequate infrastructure and limited institutional support (Alabi, 2017; Tamiselvan et al.). These challenges restrict teachers' ability to integrate digital tools into ecology lessons, therefore many classrooms teachers still rely on traditional lecture-based methods that may not fully inform students or develop their problem-solving ability. Lack of continuous professional development, unreliable power electricity and poor internet connectivity further compound the problem, leaving teachers ill-prepared to welcome innovative teaching methods (UNESCO, 2017). Addressing these systemic constraints is therefore necessary for realizing the pedagogical benefits of ICT in ecology teaching and learning.

Enhancing biology teachers' digital competence may surely transform ecology teaching and sustainability by enabling the use ICT tools such as simulations, virtual labs, multimedia resources, zoom conference learning, google note and voicemail, Email and collaborative online projects that make difficult environmental processes concrete and meaningful (Shokeen et al.; Prakash & Naik, 2018). Sincerely competent teachers may be able to design lessons that foster inquiry, creativity and higher-order thinking, while connecting students to global resources and environmental initiatives. Such pedagogical shifts not only enhance content mastery but also educational sustainability and cultivate students' capacity to become successful, improve and important environmental citizens with their knowledge. In this way, strengthening teachers' ICT skills aligns closely with broader goals of sustainable development and environmental education (Prakash & Naik; UNESCO 2017).

Information and communication technology (ICT) has focused central on education globally, some biology teachers in Nigeria still demonstrate low ability to embed digital equipments efficiently into ecology teaching and learning. For example, Ugbaja and Okeke (2020) asserted that biology teachers in Anambra State do lack the required ICT competences to use ICT tools for biology teaching and learning. Close related to it, Inyang and Uchegbue (2020) found that while many biology teachers in Calabar have basic ICT skills, only a little of proportion of them have high-level internet competency or use computers regularly in their lesson delivery. Other researchers highlight that beyond competence, there are obstacles in availability and utilization of ICT resources. In Ekiti State, for instance, Falemu and Akinwumi (2022) asserted that they're low levels of availability and utilization of ICT for biology teaching and also found out of six identified ICT tools for biology teaching and learning in ecology, only two were adequately available, and many teachers did not frequently use them. In Ilorin, existing research shows that teachers generally perceive digital literacy skills as relevant, but there is differences in actual digital competence and utilization (Agarry, Babalola, & Jacob, 2024).

With respect to this, there is a clear gap: even with the recognized values of digital competence, many biology teachers lack the needed skills, resources, or institutional support to embed ICT effectively into ecology education. This gap likely undermines students' understanding of ecological issues and their capacity to engage with sustainable practices. Therefore, this study aims to investigate how improving biology teachers' digital competence in senior secondary schools in Ilorin can advance sustainable ecology education, bridging the gap between curriculum goals and actual classroom practice.

Research Purposes

1. Examine the level of digital competence among Biology teachers in ecology teaching.
2. Investigate the level of instructional effectiveness of Biology teachers in ecology education.
3. Determine the extent of utilization of digital instructional resources in teaching ecology.
5. Examine the relationship between Biology teachers' digital competence and instructional effectiveness.

Research Questions

1. What is the level of digital competence among Biology teachers in ecology teaching in Senior Secondary Schools in Ilorin?
2. What is the level of instructional effectiveness of Biology teachers in ecology education?
3. To what extent do Biology teachers utilize digital instructional resources in teaching ecology?

Research Hypothesis

H_{o1}: There is no significant relationship between Biology teachers' digital competence and instructional effectiveness in ecology education.

Methodology

This study adopted a descriptive survey research design to investigate the digital competence and instructional effectiveness of Biology teachers in ecology education in senior secondary schools in Ilorin, Nigeria. The design was considered appropriate because it enabled the researcher to obtain quantitative data on Biology teachers' digital competence, utilization of digital instructional resources, instructional effectiveness, and the challenges associated with integrating digital technologies into ecology instruction. The target population comprised all Biology teachers in public and private senior secondary schools in Ilorin, Nigeria. A multistage sampling procedure was employed. At the first stage, stratified sampling technique was used to classify senior secondary schools into public and private schools. At the second stage, simple random sampling technique was used to select the required schools from each stratum. At the third stage, purposive sampling technique was used to select Biology teachers from the sampled schools because they taught ecology and possessed the required information for the study. A total of 120 Biology teachers constituted the sample for the study.

Data were collected using a researcher-developed questionnaire titled Digital Competence and Instructional Effectiveness Questionnaire (DCIEQ). The questionnaire consisted of four sections. Section A elicited information on the demographic characteristics of the respondents. Section B assessed Biology teachers' digital competence. Section C measured Biology teachers' instructional effectiveness in ecology education, while Section D assessed the extent of utilization of digital instructional resources in teaching ecology. The instrument was subjected to face and content validation by three experts in Science Education and Educational Technology from the University of Ilorin. To establish its reliability, a pilot study was conducted using fifteen Biology teachers selected from senior secondary schools outside the study area. The responses obtained were analysed using Cronbach's Alpha reliability coefficient, which yielded a reliability index of 0.803, indicating that the instrument possessed a high level of internal consistency and was suitable for the study.

Approval was obtained from the relevant school authorities before the administration of the questionnaire. With the assistance of trained research assistants, copies of the questionnaire were administered to the respondents during school hours and retrieved immediately after completion. Participation in the study was voluntary, and the respondents were assured of the confidentiality and anonymity of the information they provided. The data collected were analysed using descriptive statistics comprising frequency counts, percentages, mean, and standard deviation to answer the research questions, Decision Rule: The benchmark mean of 2.50 was used for decision-making. Mean scores of 2.50–3.24 were interpreted as Moderate, 3.25–4.00 as High, while 1.00–2.49 were regarded as Low.. The formulated hypothesis was tested using Pearson Product Moment Correlation (PPMC) at the 0.05 level of significance.

Results

Demographic characteristics of respondents

Table 1: Distribution of respondents base on Gender

Gender	Frequency	Percentage %
Male	50	41.67%
Female	70	58.33%
Total	**120**	**100%**

Table one: Shown that 50 (41.67%) of the respondents were male biology teachers, while 70(58.33%) of the respondents were female biology teachers. This indicates that female biology teachers constitude the large proportion of the respondents who participated in the study.

Table 2: Distribution of respondents by Age

Age	Frequency	Percentage(%)
20-30	35	29.17%
31-40	45	37.50%
41-50	25	20.83%
51-60	15	12.50%
Total	**120**	**100%**

Table two: Indicated that 45 (37.50%) of the respondents were 31 and 40 years of age, which represent the highest proportion of the teachers.Followed by aged 20–30 years (29.17%), while 20.83% were between 41 and 50 years. While the smaller respondents of 12.50% were between 51 and 60 years of age.

Table 3: Distribution of respondents by year of teaching experience

Year of experience	Frequency	Percentage(%)
1 - 5 years	35	29.17
6 - 10 years	40	33.33
11 - 15 years	25	20.83
16 - 20 years	15	12.50
Above 20 years	5	4.17
Total	**120**	**100**

Table Three Indicated that 40 (33.33%) of the respondents had between 6 and 10 years of teaching experience, which represents the highest proportion of the Biology teachers. Followed by 35 (29.17%) respondents with 1–5 years of teaching experience, while 25 (20.83%) had 11–15 years of experience and 15 (12.50%) respondents had 16–20 years of teaching experience, whereas only 5 (4.17%) had more than 20 years of teaching experience.

Table 4: Research question one; What is the level of digital competence among Biology teachers in ecology teaching in Senior Secondary Schools in Ilorin?

S/N	Items	Mean	SD	Decision
1	I can confidently use Microsoft Word to prepare Biology lesson materials.	3.12	0.76	High
2	I am competent in using digital instructional devices such as projectors and interactive boards during ecology lessons.	2.18	0.84	Low
3	I can effectively search for and integrate online educational resources into ecology teaching.	2.24	0.81	Low
4	I am skilled in using digital communication platforms (Google Classroom, Zoom, Microsoft Teams, WhatsApp) for teaching Biology.	2.31	0.79	Low
5	I regularly participate in ICT-related workshops and professional development programmes	3.08	0.73	High
	Grand Mean	**2.59**	**0.79**	**Moderate**

Table 4 indicated that Biology teachers possess a moderate level of digital competence (Grand Mean = 2.59, SD = 0.79). The respondents demonstrated relatively high competence in using basic computer applications for lesson preparation (Mean = 3.12) and regularly participating in ICT-related professional development programmes (Mean = 3.08). However, they reported low competence in the use of advanced instructional technologies such as projectors, interactive boards, online educational resources, and digital communication platforms for ecology teaching.

Table 5; Research question two, What is the level of instructional effectiveness of Biology teachers in ecology education?

S/N	Item's	Mean	SD	Decision
1	I achieve my stated learning objectives during ecology lessons	2.73	0..74	Moderate
2	My teaching helps students understand ecology concepts effectively.	2.41	0.79	Low
3	My instructional methods promote students' critical thinking and problem-solving skills in ecology learning.	2.36	0.77	Low
4	I encourage active student participation during ecology lessons.	2.21	0.82	Low
5	I effectively achieve the instructional objectives of ecology lessons through digital technologies	3.14	0.69	Moderate
Grand Mean		**2.57**	**0.76**	**Moderate**

Table 5 shows that the instructional effectiveness of Biology teachers in ecology education is moderate (Grand Mean = 2.57, SD = 0.76). The respondents reported moderate effectiveness in achieving instructional objectives and managing classroom activities. They also indicated relatively low effectiveness in promoting students' understanding, participation, and critical thinking during ecology instruction.

Table 6; Research question three what is the extent of utilization of digital instructional resources in teaching ecology?

S/N	Items	Mean	SD	Decision
1	I regularly use multimedia presentations (e.g., PowerPoint) when teaching ecology concepts	2.68	0.78	High
2	I use digital instructional resources such as educational videos, animations, and simulations to facilitate ecology teaching	2.29	0.82	Low
3	I integrate online learning platforms and digital resources to support students' learning of ecology concepts.	2.21	0.85	Low
4	I encourage students to use digital resources for assignments, research, and presentations in ecology.	2.47	0.76	Low
5	I utilize internet-based resources and virtual learning materials to enhance students' understanding of ecology	2.38	0.81	Low
	Grand Mean	**2.41**	**0.80**	**Low Extent**

Table 6 indicates the extent of which Biology teachers utilize digital instructional resources in teaching ecology. The table reveal a low level of utilization with a grand mean of 2.41 (SD = 0.80). The respondents reported a relatively high utilization of multimedia presentations such as Microsoft PowerPoint during ecology lessons (Mean = 2.68), they indicated low utilization of other digital instructional resources, including educational videos, animations, simulations, online learning platforms, internet-based instructional materials, and digital resources for students' assignments and presentations.

Research hypothesis

Table 7; H_{01}: There is no significant relationship between Biology teachers' digital competence and instructional effectiveness in ecology education.

Variables	N	r	P-value	Decision
Digital Competence	120	O.64	< 0.001	Not Accepted
Instructional effectiveness	120			

Table seven indicated that calculated Pearson correlation coefficient ($r = 0.64$) produced a p-value less than 0.05 ($p < 0.001$), the null hypothesis was rejected. This showed that there is a statistically significant positive relationship between Biology teachers' digital competence and instructional effectiveness in ecology teaching in senior secondary schools in Ilorin, Nigeria. The Biology teachers with higher levels of digital competence tend to demonstrate greater instructional effectiveness during ecology teaching.

Findings of the study

1. Research question one found that Biology teachers in senior secondary schools in Ilorin possessed a moderate level of digital competence, with high competence in basic computer applications such as Microsoft word but low competence in the use of advanced digital instructional technologies such as projects, interactive board and video simulation.
2. Research question one found that the instructional effectiveness of Biology teachers in ecology education was moderate, although the integration of digital technologies into classroom teaching remained limited.
3. Research question three found that Biology teachers utilized digital instructional resources for ecology teaching to a low extent, with PowerPoint being the most frequently used resource, while educational videos, simulations, online platforms, and internet-based materials were rarely utilized.
4. While the hypothesis tested found that The there was a statistically significant positive relationship between Biology teachers' digital competence and instructional effectiveness in ecology education ($r = 0.64$, $p < 0.001$), indicating that higher digital competence was associated with greater instructional effectiveness.

Conclusion

This study concluded that Biology teachers in senior secondary schools in Ilorin possess a moderate level of digital competence also they demonstrate a moderate level of instructional effectiveness in ecology teaching. Why the utilization of digital instructional resources remains low, as teachers rely mainly on basic digital tools such as Microsoft Word and PowerPoint while making limited use of advanced technologies, including educational videos, simulations, PowerPoint, online learning platforms, and virtual instructional resources. The study further established a significant positive relationship between Biology teachers' digital competence and instructional effectiveness, which indicated that improvements in teachers' digital competence are likely to enhance the quality and effectiveness of ecology instruction in senior secondary schools.

Recommendations

1. School administrators and education stakeholders should organize regular ICT training and professional development programmes to enhance Biology teachers' digital competence in ecology teaching.
2. Government and school management should provide adequate digital instructional facilities, reliable internet access, and technical support to facilitate the effective integration of technology into ecology instruction.
3. Biology teachers should be encouraged to increase the utilization of diverse digital instructional resources, such as educational videos, simulations, virtual laboratories, and online learning platforms, to improve students' learning experiences in ecology.

4. Educational policymakers should incorporate digital competence into teacher development policies and continuously monitor its implementation to improve instructional effectiveness in senior secondary school Biology education.

Suggestions for Further Study

1. Future studies should investigate strategies for improving Biology teachers' competence in the use of advanced digital instructional technologies for ecology teaching.
2. Researchers should examine other factors that influence Biology teachers' instructional effectiveness beyond digital competence.
3. Others researcher can explore the barriers to the utilization of digital instructional resources and evaluate interventions that can increase their use in ecology teaching.
4. Future research should also investigate whether enhancing Biology teachers' digital competence through professional development programmes leads to improved instructional effectiveness using an experimental research design.

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ENHANCING PERSONALIZED BOOK RECOMMENDER SYSTEM

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Abstract

Recommender systems (Rs) are widely used to provide recommendations for a collection of items or products that may be of interest to user or a group of users. Because of its superior performance, Content-Based Filtering (CBF) is one of the approaches that are commonly utilized in real-world Rs using Time-Frequency and Inverse Document Frequency (TF-IDF) to calculate document similarities. However, it computes document similarity directly in the word-count space. We propose a user-based collaborative filtering (UBCF) method to solve the problem of limited in content analysis which leads to a low prediction rate for large vocabulary. In this study, we present an algorithm that utilises Euclidean distance similarity function, to solve the identified problem. The performance of the proposed scheme was evaluated against the benchmark scheme using different performance metrics. The proposed scheme was implemented and an experimentally tested by using the benchmark datasets (Amazon review datasets). The results revealed that, the proposed scheme achieved better performance than the existing recommender system in terms of Root Mean Square Error (RMSE) which reduces the errors by 29% and also increase the Precision and Recall by 51.4%, and 55.8% respectively in the 1 million datasets.

Keywords: *Recommender System, Content-Based, Collaborative Filtering, Personalized Recommendations, Similarity Function*

Introduction

The rapid growth of the World Wide Web increases the difficulty of finding information related to users' information needs. Since the 1990s, efforts have been directed toward tackling this problem through the use of recommender systems. Recommender systems are information filtering systems that deal with the problem of information overload (Prem & Vikas, 2010). They work by selecting vital information fragments from a large amount of dynamically generated information based on the user's preferences, interests, or observed behavior concerning the item (Pan & Li, 2010). They can also predict whether a specific user would prefer an item or not, based on the user's profile. Furthermore, they benefit both service providers and users (Pu et al., 2010). Commercial applications of recommender systems include e-commerce, e.g., Amazon and eBay (Sanjeevan et al., 2014); fashion, food, and restaurants (Kang & Seong, 2007); and social events and art, e.g., movies, music, and books (George & Petros, 2008). In these areas, recommender systems provide excellent personalized suggestions that significantly increase the likelihood that a customer purchases a product or selects an item compared with non-personalized suggestions.

Recommender systems are categorized into four approaches: content-based, collaborative, and hybrid (Bobadilla et al., 2013). The content-based filtering technique is based on the description

of the items and a profile of the user's preferences (Priyanga & Kamal, 2017). It uses user-item similarities for recommendation purposes. In this kind of recommender system, the items recommended to a given user are those similar to the ones previously liked by the user (Hanani et al., 2001; Lops et al., 2011; Zamani & Shakery, 2018). Collaborative filtering (CF) is the most widely used system because it is used to recommend different types of products, e.g., music, news, books, and movies (Gong & Softw, 2010). The basic concept behind CF is based on collecting and analyzing a large amount of information on users' preferences and predicting what users will like based on similarity to other users. A hybrid approach combines two or more recommendation strategies in different ways to benefit from their complementary advantages.

Various studies have been proposed on book recommender systems to address low prediction rates, limited content analysis, new-user problems, and overspecialization. For example, Sarun and Paween (2018) proposed a personalized book recommender system for bookstore management using a Term-Frequency and Inverse Document Frequency (TF-IDF) model for calculating the similarity between books. However, the method sometimes recommends books that do not match what the user needs, because the TF-IDF method only uses book titles to calculate similarity between books.

In this work, an Enhanced Personalized Book Recommender System (EPBRS) is presented for bookstore management to improve the quality of recommendations and prediction accuracy. The system incorporates a Euclidean distance similarity function into the existing personalized book recommender system, using the EPBRS algorithm to recommend books that match what the user needs. The experimental study conducted indicated that, compared with the existing PBRS system, the proposed EPBRS system improves the precision, recall, and RMSE on the 1 million dataset used, thereby providing better book recommendations to target users.

Related Works

Chhavirana and Sanjay (2012) investigated a book-recommendation system that uses a content-based approach to recommend products to a specific user by employing a temporal dimension. The temporal dimension takes into account the number of times an item is liked by the user over time and stores a counter for each item, updated whenever a user checks the items in their favorite links. The results show that the proposed book recommendation engine architecture provides users with diverse and temporally updated recommendations that are more useful and relevant. However, the system incorporates contextual information, takes multiple ratings, and provides a more flexible recommendation that could also extend into different domains.

Sarun and Paween (2018) proposed a personalized book recommender system for bookstore management using TF-IDF. The TF-IDF method is based on the bag-of-words (BoW) model, where the titles of the books are converted into BoWs. The system sometimes recommends books that are not what the user needs, because the TF-IDF method uses only the title to compute

similarity directly in the word-count space, which leads to a low prediction rate. This makes the recommendations less relevant to users.

Suthathip and Songrit (2010) suggested a novel approach to recommend customized book lists to university members by using the k-means clustering technique to create clusters of users, as well as using user transaction history, and then recommending custom book lists to users within those clusters. The algorithm used a questionnaire survey to evaluate the accuracy of individual booklists. The result shows the possibility of using the history of circulation activity to predict an individual member's current interest and build a personalized booklist that suits their interests. The suggested books are, however, a poor representation of user needs due to the lack of consideration of actual book content.

Jomsri (2014) proposed a library book recommendation system based on user profiles and applied association rules for model creation. It uses library loan records and the technique of association rule mining to recommend books in the digital library. The scheme uses an association rule mining system to make inferences and derive interesting rules, as computer students are more likely to be interested in computer and math books rather than geography. Using the Amazon review dataset, the algorithm was tested using precision and recall metrics. The result showed that the new association rule algorithm is suitable for use in a library to recommend books. However, the method is restricted to finding rules that suit the needs of users who do not frequently visit libraries and conduct transactions.

Chen et al. (2019) proposed a novel collaborative filtering recommendation algorithm based on user correlation and evolutionary clustering. First, the score matrix is pre-processed with normalization, and dimension reduction is applied to obtain denser score data. Based on these processed data, clustering principles are generated and dynamic evolutionary clustering is implemented. Second, the algorithm considers nearest neighbors by applying user correlation to choose nearest neighbors for rating prediction. The proposed method is evaluated using the MovieLens dataset. Experimental results demonstrate that the proposed method has outstanding performance in prediction accuracy and recommendation precision. However, the system did not address data sparsity.

Xia et al. (2020) proposed a neural collaborative filtering recommender method that integrates user and item auxiliary information. It used an Auto-Encoder to extract user features and a Gated Recurrent Unit with auxiliary information to extract items' latent vectors. An attention mechanism was also used to learn key information when extracting text features. The experimental results show that the GANCF model achieves better results on the two datasets than other methods, and that considering auxiliary information in deeper learning can improve recommendation performance. However, users' interests sometimes change over time.

Liao et al. (2021) proposed an improvement to the Ant Collaborative Filtering (ACF) algorithm by introducing the k-means algorithm to perform an initial clustering of users according to their preferences, represented by pheromones, of which there are far fewer than the number of users.

The experiments were conducted on several large datasets, including MovieLens 10M, Douban Book, and NetEase Music. The results demonstrate the method's superiority over the ACF algorithm in both rating-based and ranking-based recommendation scenarios. However, a common problem with k-means is determining the parameter k, the number of clusters.

Methods

This section describes the proposed enhanced book recommender system.

3.1 Problem Formulation

The review of the related works was conducted which led to the identification of the research gap in the existing literature. The personalized book recommender algorithm for bookstore management based on the Term-Frequency and inverse document frequency (TF-IDF) method uses title of the books in form of BoWs model to recommend books to users. But, the system sometimes recommends books that are not what the user needs because it only utilizes book titles to compute document similarity directly in the word-count space, which lead to a low prediction rate for large vocabulary.

3.2 Enhanced Personalized Book Recommender System (EPBRS)

A colon is inserted before an equation is presented, but there is no punctuation following the equation. All equations are numbered and referred to in the text solely by a number enclosed in a round bracket (i.e., (3) reads as "equation 3"). Ensure that any miscellaneous numbering system you use in your paper cannot be confused with a reference [4] or an equation (3) designation.

EPBRS is a Personalized Book Recommender System that uses different approaches, including collaborative, hybrid, content-based, knowledge-based and utility-based filtering. In this paper, we incorporate collaborative filtering along with Euclidean distance. The EPBRs system processing can be mainly divided into three steps: Collecting user rating data matrix, selecting similar neighbors by measuring the rating similarity, and predicting target user ratings. The user rating data consists of users, items, and user ratings on observed items in the form m × n matrix, where m presents the total number of users and n presents the total number of items. Rm,n is the ratings given to item n by user m.

3.2.1 User-Book Rating Matrix

Table 1: User Books Ratings

Review ID	U1	U2	U3
Book1	5	2	4
Book2	3	4	3
Book3	1	4	1
Book4	2		?
Book5	5	2	?

Table1 shows the rating matrix consisting of users rating on books. To find the m user that exhibited similar interest with other users. It can be seen that user1 (U1) and user3 (U3) prefer book1 over user2 (U2). In addition, when it comes to book3, both U1 and U3 dislike it more than

U2. Also U1 is more similar to U3. Looking at book1, it can be seen that U3 and U1 both like it, while U2 does not. For book 3, both U1 and U3 disliked it, whereas U2 liked it as seen in Table 1. It is obvious that U1 is more similar to U3, so we get other books that U1 has read but U3 has not. As a result, book5 can be recommended to U3 because U1 has already read it five-time.

3.2.2 Similarity Calculation

The similarity calculation is a fundamental stage in the recommendation process. In this case, the similarity of user × user are computed from table 1 using equation (1) and the results are presented as follows:

$$Sim\,(p,q) = \sqrt{\sum_{i=1}^{n}(p_i - q_i)^2} \qquad (3.1)$$

Where, (p, q) refers to dimensional vectors between two users or items and n is the number of items.

$$Sim\ (P_1, P_1) = \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2 + (x_3 - y_3)^2}$$

$$Sim\ (P_1, P_1) = \sqrt{(5-5)^2 + (2-2)^2 + (4-4)^2}$$

$$Sim\ (P_1, P_1) = \sqrt{(0)^2 + (0)^2 + (0)^2}$$

$$Sim\ (P_1, P_1) = \sqrt{0+0+0}$$

$$Sim\ (P_1, P_1) = \sqrt{0}$$

$$Sim\ (P_1, P_1) = 0$$

Table 2: User × User Similarity Computations

User	A	B	C	D	E
A	0.000000	0.000000	0.000000	0.160768	0.240253
B	0.000000	1.000000	0.261204	0.366025	0.500000
C	0.000000	0.261204	1.000000	0.000000	0.158945
D	0.160768	0.366025	0.000000	1.000000	0.151342
E	0.240253	0.500000	0.158945	0.151342	1.000000

Consider Table 2 below we intuitively decided not to take all neighbors into account (neighbor selection) for the calculation of the predictions, we included only those that had a positive correlation with the active user (and of cause, had rated the item for which we are looking for a prediction) if we included all users in the neighborhood, this would not only negatively influence the performance concerning the required calculation time, but it would also affect the accuracy of the recommendation, as the ratings of other users who are not comparable would be taken into account.

3.2.3 Rating Prediction

After computing the similarity between user x and with any other users, select the k users with highest similarity values as set N. Then, we try to estimate the rating of item i by the user x and make sure that the set N consist only of users actually rated item i. finally, we make a prediction for user x and item i using a weighted average rating from the neighborhood as in equation (2):

$$r_{xi} = \frac{\sum_{y \in N} S_{xy} \times r_{yi}}{\sum_{y \in N} S_{xy}} \quad (3.2)$$

Where S_{xy} is the similarity of user x and y.

r_{yi} is the rating of user y on item i

N is the set of k users most similar to x who has also rated item i

r_{xi} is the prediction for user x and item i

Some sample prediction computations results are demonstrated in Table 3 by using the equation (2) above and the EPBRS algorithm.

Where S_{xy} is the similarity of user x and y.

r_{yi} is the rating of user y on item i

N is the set of k users most similar to x who has also rated item i

Table 3 Enhanced Personalized Book Recommender System (EPBRS) Algorithm

Component	Description
Algorithm	Enhanced Personalized Book Recommender System (EPBRS)
Input	Amazon review dataset containing reviews, metadata, items, and user-item rating information.
Output	Predicted item ratings for users.
Procedure	**Step 1:** Load the dataset. **Step 2:** Perform data visualisation and exploratory analysis on the dataset. **Step 3:** Conduct feature engineering by removing unnecessary features, columns, and ratings for each user. **Step 4:** Randomly split the user ratings into training and testing datasets to minimise data bias. **Step 5:** Perform error analysis for each item.

Component	Description
	Step 6: If an item rating is greater than 5, set the item rating equal to 5 for each user. **Step 7:** If the number of ratings for an item is greater than one, replace the item rating with the mean rating of that item across users. **Step 8:** Create a User × Item matrix from the review data. **Step 9:** Compute the items viewed or rated by each user. **Step 10:** Create a User × User review-by-item matrix. **Step 11:** Compute the User × User similarity matrix using the Euclidean distance similarity function (Equation 1). **Step 12:** Generate predicted user ratings for all items using the User × User similarity matrix obtained in Step 11 and the prediction model in Equation 2.

Lines 1-4 of the algorithm represent the data collection and cleaning of the Amazon book review data. The data would be represented as an m x n matrix.

Lines 6 - 7 of the algorithm is to perform around check if any item ratings are greater than five to ignore it and set the item rating to be equal to five for each user. Also if the number of each item rated is greater than one then, we take the average ratings of that particular item to minimize error analysis from the dataset.

Lines 8 – 9 of the algorithm is to create a user x item matrix from the review data and we compute items seen/rated by each user.

Lines 10 – 12 of the algorithm is to create a user x user matri x with a pivot table and in each column, we compute user x user similarity matrix using Euclidean distance to see the distance between the user ratings.

Finally, we generate user ratings for all items using the user matrix obtain in step 11.

Experiments and Results

This section discusses the experimental setup to evaluate our proposed EPBRS system. The effectiveness of the system was evaluated by measuring the recommendation quality using precision, recall, and RMSE evaluation metrics.

4.1 Experimental setup

We used computer Intel (R) Core i5-4310 2.6-GHz with 8 GB memory running Windows 10 Pro. The proposed system was implemented in Python 3.9 with Pandas 0.8.0 Library, SCIKITLearn.

4.2 Data set

The Amazon review dataset will also be considered in evaluating the performance. This dataset consists of 12,886,488 book reviews associated with information about books, users, and their ratings. The time and effectiveness of each review are given and it can be easily extended to include more information about books, but not about users (McAuley & Leskovec, 2013). Moreover, the Amazon API delivers item lookup not limited to books and similarity lookup that returns a list of similar products (usually presented to customers as recommendations).

Amazon dataset was used in the two experiments. We compare our proposed approach with a recommendation based on bestselling books by Sarun and Paween (2018) using the Amazon dataset. We used four fold cross-validation. We divided the users into the ratio of 3:7 where 70% of the existing users were used for training, while 30% of the users were used for test data. We 30% of the users as cold users in which interest had already been known.

Table 3: Prediction using weighted average ratings from the neighborhood

Review ID	**Actual Rating**	**Reviewer ID**	**ASIN**	**Unix Review Time**	**Predicted Rating**
21405182	3.0	A108M62RB1HTC0	1682307913	1486425600	4.759705
20635353	5.0	A3RF010MX29BQP	1939713293	1435622400	4.590341
15184590	5.0	A277TO3PKKNYDH	1479327573	1351382400	4.465197
22080126	5.0	ALY4MQYVAEE4U	1494563258	1408924800	4.719279
15220283	5.0	A3526B1LCK47X9	1480114480	1353456000	4.282797
6674239	5.0	A3KAKFHY9DAC8A	0446549150	1421107200	4.262266
7060988	5.0	A1WH1YZ5VGTKXG	0451475682	1423008000	4.486042
11757895	5.0	A5FDYZB6MG2TT	0989104400	1375833600	4.302070
21845648	5.0	A2L7N2U5Z316ZE	B000X1MX7E	1268438400	4.590768
17506615	4.0	ASZ8NR9HIZGJF	1519028520	1475971200	4.315153

Table 4: Overall Result of our proposed scheme

Data Size	Model	RMSE	Average Precision	Average Recall
1 Million	PBRS	0.973	0.37	0.35
	EPBRS	0.683	0.53	0.53

{
Category:"Books New, Used & Rental Textbooks
Medicine & Health Sciences"
"Books Arts & Photography Music"
"Books Arts & Photography Music"
Title: Biology God: Living Creation Third
Edition 10 (A Beka Book Science Series)
Mksap 16 Audio Companion: Medical Knowledge
Self-Assessment Program
Flex! Discography of North American Punk,
Hardcore, and Powerpop 1975-1985 A-M
Heavenly Highway Hymns: Shaped-Note Hymnal
Georgina Goodman Nelson Womens Size 8.5 Purple
Regular Suede Platforms Shoes
Principles of Analgesic Use in the Treatment of Acute Pain and Cancer Pain
(APS, Principles of Analgesic Use in the Treatment of Acute Pain and Cancer Pain)
MKSAP 15 Audio Companion"
Rank:"1349781, 1702625, 6291012, 2384057, 11735726, 1906939, 2236549".
Price: "92878, 000047715X, 4545,13765,116,555010, 477141"
Rating: "5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5"
Asin: "92878, 000047715X, 4545, 13765, 116, 555010, 477141"
}

Fig. 1 Sample Amazons book review

4.3 Result and Discussion

In this section, the results of the improved bestselling approach were presented and discussed.

4.3.1 Results

In the section below, results of the similar user's interest and bestselling book were presented. It was obtained that the result of similar user interest and best bookselling books was better than that of bestselling books approach alone. Table: 6 below presents an overall result of RMSE, Precision, and Recall respectively. Prediction ratings, the total number of ratings, and the actual number of ratings were obtained from the Amazon dataset.

4.3.2 Discussion

Across all the evaluations in Table 4, results show that the user interest similarity PBRS technique and the bestselling books approach to achieve better RMSE, Precision, and Recall in 1 Million datasets than the work [12]. In the 1million dataset, there is an improvement in RMSE, Precision, and Recall of 29.8%, 51.4%, and 55.8% as presented in Fig. 1, Fig. 2 and Fig. 3 respectively. It can be seen from the results that, the EPBRS model achieves the lowest RMSE values than PBRS with higher average precision and recall for the 1 million dataset. Therefore, it shows better prediction performance which helps in recommending books of interest to the users.

The reason for this performance is because the PBRS moderately penalized high rating items since they can be of interest to the active users. It ignores the penalty on the items with fewer ratings to improve their chances of being predicted. It also indicated that taking into account the dataset's item popularity level played a better role in predicting items of interest to users. As a result, the proposed not only enhances the accuracy of rating prediction but can also help to predict more interesting bestselling books to users.

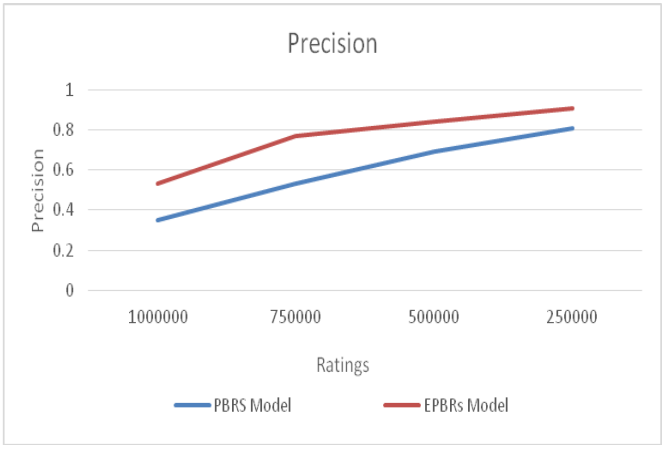

Fig. 2 Precision 1 Million dataset size

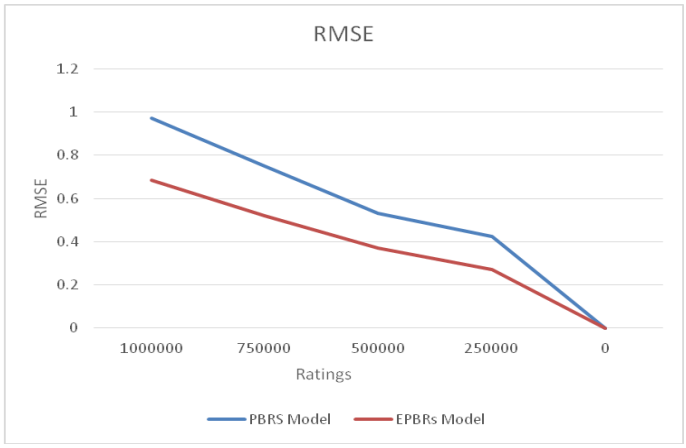

Fig. 3 RMSE 1 Million dataset size

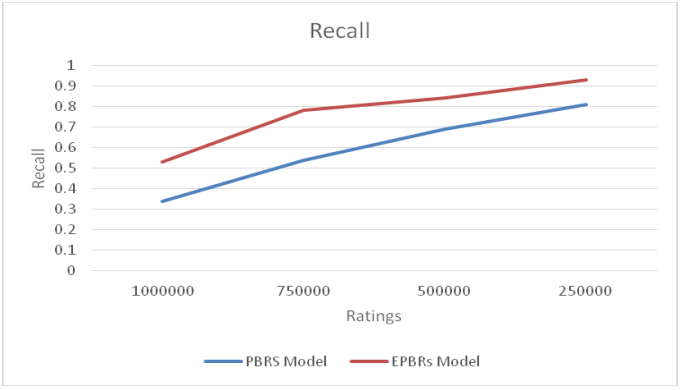

Fig. 4 Recall 1 Million dataset size

Conclusion

We proposed an Enhanced Personalized Book Recommender System (EPBRS) by utilising the Euclidean Distance Similarity Function. The scheme employs Euclidean distances similarity function to locate users with similar interests and books of interest. A user is recommended one of their books of interest that are bestselling books to users. The book's ratings were used as feature sets for bestselling predictions. The evaluation was performed using the "Amazon review dataset" and the results showed that the RMSE, Precision, and Recall improved by 29.8%, 51.4%, and 55.8% respectively in the 1 Million datasets. However, in our future work, we will incorporate different machine learning and clustering algorithms to allow regrouping of all books based on the ratings and user preferences and then study the comparative results.

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THE ROLE OF INSTITUTIONAL ACCESS TO TECHNOLOGIES IN PRE-SERVICE BIOLOGY TEACHERS' READINESS AND USE OF AI FOR INSTRUCTION

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Abstract

This study investigated the role of institutional access to technologies in pre-service Biology teachers' readiness and use of Artificial Intelligence (AI) for instruction in North Central Nigeria. A descriptive cross-sectional survey design was adopted. The population comprised 1,197 pre-service Biology teachers in 20 Colleges of Education, from which 792 respondents were selected using a multistage sampling procedure. A total of 695 valid responses were analysed. Data were collected using the Pre-service Biology Teachers' Accessibility, Readiness and Use of AI for Instructional Delivery Questionnaire (PBTARUETIDQ), adapted from Rutto (2014). The instrument was validated by experts and yielded reliability coefficients of 0.77, 0.83, and 0.85 for accessibility, readiness, and use of AI, respectively. Data were analysed using frequency counts, percentages, mean scores, and t-test statistics. The findings revealed that pre-service Biology teachers had a high level of access to AI technologies (mean = 3.43) and demonstrated high readiness to use AI for instruction (mean = 3.57). However, their actual use of AI for instructional delivery was moderate (mean = 3.02), with greater use reported for content searching, lesson preparation, and assessment development, while advanced applications such as instructional analytics, personalised learning, and classroom management were less utilised. The study concluded that although pre-service Biology teachers have favourable access and readiness for AI integration, practical utilisation remains limited. It was recommended that teacher education institutions should enhance AI accessibility, provide structured AI training, and create practical opportunities for pre-service teachers to develop competence in diverse AI-supported instructional applications.

Keywords: Artificial Intelligence, Institutional Access, Pre-service Biology Teachers, AI Readiness, Instructional Delivery

Introduction

Artificial intelligence (AI) has emerged as one of the most transformative technologies of the Fourth Industrial Revolution, significantly reshaping educational systems worldwide. The rapid evolution of AI technologies has transformed conventional teaching and learning approaches by enabling personalised instruction, intelligent tutoring, automated assessment, adaptive learning environments, content generation, and data-informed pedagogical decision-making (Miao & Cukurova, 2024). Recent advances in generative AI, including large language models such as ChatGPT, Google Gemini, and Microsoft Copilot, have expanded opportunities for lesson planning, instructional material development, assessment design, scientific inquiry, and collaborative learning. Consequently, AI is increasingly recognised as a critical component of contemporary teaching and learning that requires teachers to acquire new pedagogical and technological competencies (Meylani, 2024).

The growing integration of AI into education has shifted the traditional teacher–student relationship towards a teacher-AI-student ecosystem in which teachers increasingly collaborate with AI systems to design learning experiences, generate instructional resources, provide personalised feedback, and support student learning (Miao & Cukurova, 2024). This transformation requires teachers to move beyond conventional digital literacy towards AI literacy, which encompasses understanding AI concepts, critically evaluating AI-generated outputs, applying ethical principles, and integrating AI into pedagogical decision-making. According to Miao and Cukurova (2024), effective teacher preparation for AI-enabled education requires competencies in five key domains: human-centred mindset, AI ethics, AI foundations and applications, AI pedagogy, and AI-supported professional learning.

Within teacher education, preparing pre-service teachers to utilise AI effectively has become an important institutional responsibility. Teacher education programmes are expected to produce graduates who can integrate innovative technologies into classroom instruction, enhance learner engagement, facilitate inquiry-based learning, and respond to the evolving technological demands of twenty-first-century education (Oni & Ngongpah, 2024). This expectation is particularly important for pre-service Biology teachers because Biology teaching involves abstract concepts, laboratory investigations, scientific reasoning, and complex biological processes that can be enhanced through AI-supported simulations, intelligent tutoring systems, virtual laboratories, adaptive learning platforms, and automated feedback mechanisms.

The increasing availability of AI technologies, however, does not necessarily guarantee their effective instructional integration. Recent evidence indicates that successful AI adoption depends on both individual and contextual factors. At the individual level, teachers require AI knowledge, technological self-efficacy, pedagogical competence, ethical awareness, and confidence in using AI tools. At the institutional level, universities must provide reliable internet connectivity, AI-enabled software, technical support, institutional policies, and continuous professional development opportunities (Pasi & Dhamak, 2026). Research by Cukurova, Miao, and Brooker (2023) further demonstrated that institutional support, teacher ownership, trust, and organizational mechanisms significantly predict teachers' engagement with AI technologies in educational settings.

Institutional access to AI technologies therefore represents a strategic component of teacher preparation. Institutional access extends beyond the availability of computers to include AI

software, licensed educational platforms, cloud-based applications, digital laboratories, learning management systems integrated with AI functionalities, technical support services, institutional AI policies, and structured opportunities for developing AI competencies. Universities that provide these resources are more likely to create learning environments that enhance pre-service teachers' readiness and confidence in using AI for instructional purposes (Miao & Cukurova, 2024). Conversely, inadequate institutional access may reduce opportunities for practical experience with AI technologies and limit teachers' preparedness for AI-enhanced instruction.

Literature Review

Artificial intelligence (AI) has increasingly become a significant innovation influencing contemporary instructional practices by providing teachers with tools that support planning, teaching, assessment, and learner engagement. Celik, Dindar, Muukkonen, and Järvelä (2022), in their systematic review of AI applications in education, reported that AI technologies provide opportunities for teachers to improve instructional planning, classroom implementation, and assessment practices. According to these authors, AI can assist teachers in identifying learners' needs, providing immediate feedback, and automating some assessment processes, thereby enabling teachers to focus more on higher-order pedagogical decisions.

The instructional application of AI has expanded considerably with the emergence of generative artificial intelligence (GenAI), particularly large language models capable of producing human-like text, images, explanations, and instructional resources. Miao and Cukurova (2024) argued that AI has transformed the traditional teacher–student relationship into a teacher–AI–student interaction model, requiring teachers to develop new competencies for effective and ethical AI integration. They emphasised that AI should not replace teachers but should function as a supportive tool that enhances teachers' professional judgement, creativity, and instructional effectiveness. In instructional practice, AI technologies provide opportunities for personalised learning, adaptive instruction, automated feedback, instructional content generation, and data-informed decision-making. Holmes, Bialik, and Fadel (2022) explained that AI-supported educational systems can analyse learner data, identify individual learning difficulties, recommend appropriate learning resources, and support differentiated instruction. These capabilities are particularly relevant in science education, where learners often encounter abstract concepts that require visualisation, simulation, and interactive representation.

For Biology instruction specifically, AI offers significant pedagogical opportunities because many biological processes involve complex structures, dynamic interactions, and microscopic phenomena that are difficult to explain through traditional instructional approaches. AI-powered simulations, virtual laboratories, intelligent tutoring systems, and adaptive learning platforms can provide learners with opportunities to explore biological concepts through interactive and personalised experiences. Through these technologies, Biology teachers can create inquiry-oriented learning environments that promote scientific reasoning, conceptual understanding, and active engagement.

Furthermore, AI can support Biology teachers in instructional preparation by assisting with lesson planning, generation of learning materials, development of assessment tasks, and provision of explanations suitable for different learner abilities. Celik et al. (2022) noted that AI applications

can enhance teachers' instructional efficiency by reducing routine tasks and providing analytical information that supports pedagogical decision-making. However, the authors cautioned that teachers remain central actors because AI-generated recommendations require professional interpretation and pedagogical evaluation.

Despite these opportunities, researchers have identified several challenges associated with AI integration in instruction. Holmes et al. (2022) highlighted concerns relating to accuracy of AI-generated information, algorithmic bias, data privacy, academic integrity, and ethical issues. Similarly, Miao and Cukurova (2024) argued that teachers require adequate AI competencies to critically evaluate AI outputs, apply ethical principles, and maintain human-centred educational practices. They proposed that teachers' AI competencies should include AI foundations, AI ethics, AI pedagogy, and professional learning with AI. Therefore, although AI provides considerable opportunities for improving instructional delivery, its educational value depends largely on teachers' ability to understand, evaluate, and integrate AI appropriately within specific subject contexts. This highlights the importance of examining teachers' readiness to use AI for instruction.

Readiness to use AI for instruction refers to teachers' preparedness, confidence, competence, attitudes, and willingness to integrate AI technologies into teaching and learning processes. Unlike general digital literacy, AI readiness requires deeper understanding of AI concepts, awareness of ethical implications, ability to evaluate AI-generated information, and competence in applying AI tools within pedagogically meaningful contexts. Miao and Cukurova (2024) identified teacher AI competency as a fundamental requirement for successful AI integration in education. According to these authors, teachers require competencies across five major areas: human-centred mindset, ethics of AI, AI foundations and applications, AI pedagogy, and AI-supported professional learning. These competencies suggest that readiness involves not only technical ability but also ethical judgement and pedagogical understanding.

The importance of teacher readiness is supported by technology adoption theories. Davis (1989), through the Technology Acceptance Model (TAM), proposed that perceived usefulness and perceived ease of use influence individuals' willingness to adopt technological innovations. Applied to AI integration, teachers who perceive AI as beneficial for improving instruction and manageable to use are more likely to demonstrate positive attitudes and greater willingness to incorporate AI into classroom activities. Similarly, the Technological Pedagogical Content Knowledge (TPACK) framework developed by Mishra and Koehler (2006) provides a useful explanation of AI readiness among subject-specific teachers. The framework suggests that effective technology integration occurs when teachers possess a combination of technological knowledge, pedagogical knowledge, and content knowledge. For pre-service Biology teachers, AI readiness therefore involves the ability to select and apply AI tools that appropriately support Biology concepts, laboratory activities, scientific inquiry, and learner assessment.

Recent research indicates that teachers' readiness for AI is influenced by both personal and institutional factors. Viberg et al. (2023) examined teachers' trust in AI educational technologies across six countries and found that teachers' understanding of AI and confidence in using AI significantly influenced their perceptions of AI benefits and concerns. Their findings suggest that teachers with stronger AI self-efficacy and understanding are more likely to trust and engage with AI-based educational technologies.

Institutional support also plays an important role in shaping AI readiness. Miao and Cukurova (2024) emphasised that teachers cannot develop AI competencies effectively without supportive institutional environments that provide access to AI technologies, professional development opportunities, and clear guidelines for responsible AI use. Institutions therefore serve as important facilitators of teachers' readiness by creating opportunities for experimentation, training, and practical application of AI tools. For pre-service teachers, readiness is particularly important because their experiences during teacher education influence their future classroom practices. Teacher education institutions are responsible for preparing future teachers who can confidently integrate AI into instruction. However, inadequate exposure to AI technologies during teacher preparation may limit graduates' confidence and competence in using AI when they enter professional teaching environments. Although AI readiness has received increasing scholarly attention, existing studies have mainly focused on teachers' perceptions, acceptance, and attitudes toward AI. Limited empirical evidence exists regarding the readiness of pre-service Biology teachers specifically, particularly in relation to institutional access and actual instructional use of AI. This gap indicates the need for further investigation into how institutional access contributes to the readiness and instructional application of AI among future Biology teachers.

Accessibility to digital tools may influence the integration of AI into education. Okada (2018) identified accessibility as one of the major challenges that hindered the wide use of new technologies in education. In many developed countries, this is not a problem, there is easy access to computers for students, their teachers and the school administrators (LeCun, 2022). This is not the case for a developing country such as Nigeria and many other countries in Africa. Accessibility to these digital tools is a bridge to educational equity, allowing teachers to reach every student, regardless of their background. Competency in these technologies is the ink with which they will pen the future of education, crafting lessons that resonate and engage. AI are the new chalk and blackboard, They are the silent but active partners in a teacher's quest for professional growth, offering a path to meet the ever-changing demands of the educational landscape if teachers are aware of them, have access to them and use them.

Adomi and Kpangban (2010) noted that in many Nigerian institutions, access to modern technology is improving but remains inconsistent due to infrastructural limitations, especially in rural areas. Agbo (2020) also highlighted the uneven distribution of technology across educational sectors, pointing out that while some students have access to cutting-edge tools, many still struggle with partial or complete inaccessibility due to economic and geographical barriers. Additionally, Mtebe and Raisamo (2014) found that access to educational technology in sub-Saharan Africa is significantly influenced by socio-economic factors, which aligns with the variability in access shown in the table. Admin (2020) highlighted that access to AI in Nigerian education is gradually improving, especially in urban areas, but still faces challenges in rural settings, where infrastructure limitations persist. Similarly, Alimi et al. (2024) found that although many Nigerian teachers are aware of and ready to adopt new technologies, limited access, especially in public institutions, remains a major barrier to full integration. These studies underline the persistent challenge of equitable technology access in Nigerian education systems, particularly for pre-service teachers in regions like North Central Nigeria. Without improving access to AI, the potential benefits of digital learning may remain out of reach for a significant portion of the population.

The usability of AI for teaching and learning refers to how effective the employment of new digital tools would be for planning, complimenting, enhancing or delivering instruction in or outside the classroom environment. Holden and Rada (2011) posited that the use of any form of technology in the teaching process is largely dependent on the acceptance, perceived usability and satisfaction of the user. Bolaji and Adeoye (2022) researched the level of accessibility, usability and utilization of ICT tools for monitoring educational practice in secondary schools. The researchers employed a cross-sectional descriptive method for the study, the samples were selected randomly from the population and included teachers from public and private schools, composed of males and females. The instrument used was a structured questionnaire with three sessions which was used to elicit information from respondents. Three research questions were answered, and the findings revealed that the major reason teachers are not using ICT tools is the issue of accessibility.

Holden and Rada (2011) worked on the Influence of perceived usability and technology self-efficacy on teachers' technology acceptance. The research was a descriptive survey administered to sampled K-12 teachers in two rural School districts in Virginia. The responses were analysed with reliability atatistics and general linear modelling techniques. The results indicated that perceived usability influenced teachers' technology self-efficacy and their acceptance of such technology. It also indicates that teachers' computer self-efficacy did not influence the decisions to accept and use certain technologies but their technology self-efficacy. It also indicates that teacher that teachers perceived usability of a technology influences their use of such technology. Ayanwale et al. (2024) found that while pre-service teachers in Nigeria have improved access to technology, their use is often limited by a lack of adequate training and poor infrastructure. Similarly, Mayantao and Tantiado (2024) noted that despite the growing integration of digital tools in education, many teachers still struggle with their consistent use due to limited digital literacy and resources.

Furthermore, Alieto et al. (2024) emphasised that teacher confidence and competence in using technology are critical for its successful adoption, which is still an area requiring attention in many regions. Hennessy et al. (2022) found that while there is growing awareness and use of AI in Nigerian education, pre-service teachers still face challenges such as a lack of adequate infrastructure, technical support, and consistent training in these technologies, which limits their full utilisation. Similarly, Mlambo (2018) reported that many pre-service teachers are enthusiastic about using technology, but limited access to digital resources and training on their effective use hampers their ability to integrate them consistently into their teaching. Research by Gloria and Oluwadara (2015) notes that pre-service teachers in Nigeria exhibit high intention and ease of use of e-learning technologies like interactive whiteboards and Microsoft suites. These tools are perceived as highly beneficial for future teaching.

Instructional delivery is a dynamic interaction among the students, the teacher, the contents, and the knowledge, skills, and dispositions that students need for learning to take place. It includes the methods and strategies used by educators to effectively convey information, facilitate learning and engage students in the classroom. Lukman (2023) defined instructional delivery models are methods, strategies, approaches or even techniques that a teacher employs to deliver his/her subject matter of a lesson in the classroom to the different learners. Knight (2012) noted that Instructional delivery methods are essential practices that teachers must master for effective instructional delivery and for students to maximize knowledge and skills acquisition, it has been defined in

recent times to include essential practices that teachers must put to use to effectively instruct students and enhance learning. These practices go beyond simply delivering content they involve creating an engaging and effective learning environment.

Instructional delivery involves intentional teaching techniques that promote active learning, student engagement, and effective knowledge transfer, they are characterised by the use of different pedagogical skills altogether. In the submissions of Marzano, Pickering, and Pollock (2001), Instruction that is well-planned moves students from their current level of competency toward explicit criteria for success. During teaching practice, pre-service teachers are supposed to gain practical experience working alongside experienced to chat and real school settings. The instructional delivery strategies that educators employed in recent times are not limited to traditional lectures, discussions, and field trips they include strategies that require adequate planning such as learning simulation, role-playing, content-based team-building activities, virtual field trips, what? So what? What now? Among other innovative Strategies. These strategies may require the use of one or more forms of AI to plan and/or deliver instruction.

During teaching practice, pre-service teachers learn (from the subject teacher in their place of primary assignment) to use different teaching strategies or combine more than one. The essence of the use of different instructional delivery models is to enable the instructor (pre-service teacher) to surmount the challenges of the organization and passage of the instruction to students who are assumed to have come from different backgrounds and, therefore, possess different learning styles, pace and will understand the lessons based on their previous knowledge (Lukman, 2023). In a similar study, Foulger et al. (2013) submitted that pre-service teachers (during their teachers' training programme) should be taught how to integrate technology when planning and delivering instructions. In cases where this is not the case, pre-service teachers acquire such technological skills during the teaching practice programme.

Teaching practice is a compulsory assessment programme aimed at examining pre-service teachers to ascertain the level at which they have internalized all theoretical knowledge (taught to them) in a real school environment. The teaching practice programme plays a pivotal role in shaping pre-service teachers into competent educators. It provides them with hands-on experience and prepares them for the dynamic world of teaching. Lukman (2023) submitted that the importance of the teaching practice programme cannot be overemphasised as it is crucial to teachers' professional development, and shapes their beliefs and thinking about the teaching profession. The teaching practice programme serves as a bridge between theoretical knowledge gained in the teacher education programmes and practical application in actual classrooms. It allows pre-service teachers to develop essential teaching competencies, refine their skills and help them gain confidence before they officially become teachers.

Teaching practice was defined by Kiggundu and Nayimuli (2009) as an integral part of the teachers' training programme which gives the pre-service teachers their first form of teaching experience in a real school life environment before they are certified to teach. It has a key influence on the learning of pre-service teachers' training institutions (Lukman, 2021). The programme starts with placement, then supervision to be sure that pre-service teachers gain hands-on experience, then, they are encouraged into self-reflection to be able to learn from their experiences. The skills intended for pre-service teachers to acquire during the teaching practice programme include lesson

planning classroom management assessment techniques how to overcome classroom challenges and instructional delivery.

In recent times, better pedagogical skills are acquired in a dynamic setting online if pre-service teachers belong to (or join) an online teaching practice support group where there are active guidance tips through networking and sharing of ideas (Duncan-Howell, 2009). Whatever happens during teaching practice stays with the teacher for the rest of his or her professional life. Abdulazeez et al. (2023) submitted that pre-service teachers experience different difficulties during the teaching practice programme, some of which are mostly associated with instructional delivery, acquisition and use of pedagogical skills and technologies. Lukman (2023) submitted that most students deployed for the teaching practice programme will acquire skills such as instructional planning, instructional technology, instructional delivery methods, and assessment techniques. In the study conducted by Kiggundu and Nayimuli (2009), the researchers opined that during the teaching practice programme, there is an absolute need for pre-service teachers to integrate academics, classroom teaching, and theory into practice using educational technology with different instructional delivery methods.

Abdulazeez et al. (2024b) researched pre-service Biology teachers' pedagogical skills and usability of mobile technology for instructional delivery during teaching practice. The study was carried in Ilorin, Kwara state, Nigeria and was a descriptive survey among pre-service teachers. The study addressed five research questions and tested two hypotheses, variables on accessibility and perceived usefulness, were tested. Data collected from the 285 respondents through an adapted questionnaire were analysed by descriptive and inferential statistics. The findings revealed that the lack of technological literacy of pre-service teachers is as a result of a technology-deficient teacher training program they are undergoing The findings of this study were contrary to the findings of most similar studies.

There is a lot to be done on the quality of training pre-service teachers receive. Knowledge of technology integration in the classroom should be taught to pre-service teachers in the education programmes, this plays a critical role in preparing tomorrow's teachers for the world of work. Teacher educators should have some knowledge, skills and attitudes which are needed in preparing pre-service teachers for teaching within technology-enhanced learning environments (Foulger et al 2013)**.** Teacher educators need to help pre-service teachers bridge the gap between technology, pedagogy and content knowledge when training them (Koehler & Mishra 2009)

Tondeur et al (2019) researched teacher educators as gatekeepers to prepare the next generation of teachers for technology integration in education. The research questions covered variables such as competencies to use ICT in teaching, ability to design an ICT-rich learning environment, attitudes towards ICT and strategies they use in preparing pre-service teachers for technology integration which comprise six of the SDQ model. The research was carried out in Flanders, Belgium and it sampled teacher educators. The results showed that all variables are determinants of the use of ICT for teaching future teachers and implications for future practice were noted.

Mtani and Mbelwa (2022) researched the factors affecting Learning Management System usage in higher learning institutions in Tanzania using the University of the Dodoma as a case study. The story adopts constructs from the Technology Acceptance Model (TAM) and the Unified Theory

of Acceptance and Use of Technology ($UTAUT_2$). Respondents included participants from Dodoma University the instruments used were a structured questionnaire and an interview schedule. The study adopted a mixed method research approach, the findings of the study revealed that perceived usefulness, instructors' self-efficacy and intrinsic motivation of instructors influence the usage of the learning management system among instructors in higher learning institutions in Tanzania. The findings also revealed that support from the institution plays a vital role in the use of LMS.

Martin et al. (2020) examined higher education faculty use of emerging digital technologies, their importance, the competence of the faculties and their motivation to use the technologies. The study was carried out in the United States of America and faculties from different universities responded to an online survey of the use of AI. The study was a descriptive survey the study researched the influence of faculty characteristics such as gender, teaching level, faculty rank, teaching experience, beliefs, reappointment, promotion, and tenure. The findings revealed that learning management systems were the highest in use of in terms importance and competence while Social Media was rated the lowest in terms of importance and adaptive learning in terms of competence. The findings also revealed that learning benefits were the most influential factor and tenure was the least influential factor when it comes to motivation to integrate AI.

Schina et al. (2021) found pre-school teacher acceptance and self-efficacy towards educational robotics in their pre-service teacher training programme. The study was an associational study with one-group sampling. Qualitative and quantitative data was collected before and after intervention with two pre-questionnaires and two post-questionnaires. The sample was drawn from pre-service teachers at the Rovira I Virgili University, Tarragona, Spain. Findings revealed that pre-service teacher acceptance and self-efficacy l towards educational robotics improved after they completed the educational robotic teacher training courses. The findings also showed that there was a significant difference between the pre-service teachers' acceptance of educational robotics at the beginning and the end of the course with a change in perceived ease of use and perceived usefulness.

Melki et al. (2017) researched the use of information and communication technology as a catalyst for professional development and the perception of tertiary-level faculty. The study was a descriptive survey with a questionnaire based on the UTAUT construct for eliciting responses from participants who are faculties at an institution in north Lebanon basically on the use of the learning management system and Moodle. The findings revealed that the respondents perceived ambiguity in the use of LMS and the models for teaching their courses and had positive responses regarding the importance of the integration of ICT in education for professional development. The study suggested that new and innovative technology models should be developed which will link the use of technology to faculty professional development.

Purpose of the Study

The main purpose of this study is to investigate the role of institutional access to technologies in pre-service biology teachers' readiness and use of AI for instruction in North-Central, Nigeria. Specifically, the purpose aimed to:

1. investigated the level of access of pre-service Biology teachers to AI for instruction;
2. determined the level of Readiness of pre-service Biology teachers to AI for instruction;
3. examined the level of use of AI by pre-service Biology teachers for instructional delivery.

Research Questions

1. What is the level of access of pre-service Biology teachers to AI for instruction?
2. What is the level of Readiness of pre-service Biology teachers to AI for instruction?
3. What is the level of use of AI for instruction by pre-service Biology teachers for instructional delivery?

Methodology

This study used a descriptive cross-sectional survey design. It was carried out in North Central, Nigeria. The population was all pre-service Biology teachers in colleges of education in North-Central, Nigeria. The instrument used consisted of a questionnaire which was adapted from Rutto (2014), with items covering accessibility, readiness and usability of AI for instructional delivery, respectively. The population for the study consisted of all the pre-service Biology teachers in the 60 public and private Colleges of Education in North Central, Nigeria. The target population included all the 1197 pre-service Biology teachers in the 20 Colleges of Education in North Central, Nigeria, selected using a stratified sampling technique.

Multistage sampling procedure was used in this study. The 20 sampled Colleges of Education were selected through stratification into Federal, State and Private Colleges of Education based on proportion. Year II and Year III students studying Biology combination courses in the sampled colleges were purposively selected to take part in the study based on their participation in the teaching practice programme. A proportional sampling technique was used to determine the number of respondents from each sampled institution totalling 792 respondents. Since the institutions are co-educational, samples were again stratified along gender and age.

The instrument used in this study was a questionnaire adapted from Rutto (2014) who used it for agricultural science teachers, so, it was adapted to suit pre-service Biology teachers. The 52-item questionnaire was prepared entitled "Pre-service Biology Teachers' Accessibility, Readiness and Use of AI for Instructional Delivery Questionnaire (PBTARUETIDQ)" and it has four sections A, B, and C. Section A of the instrument deals with pre-service Biology teachers' bio-data. It contains information on the respondents' school name, school type (private or public), course combination, gender, academic and age.

For Section B a four-point Likert type scale was also adopted. The section contains a list of AI to check the accessibility of pre-service teachers, with response options of Very Accessible (VAC), Accessible (A), Partially Accessible (PAC), and Not Accessible (NAC). Section C contains a 10-item list of AI to check for their readiness to use AI. The likert-type response modes of highly

ready (5), moderately ready (3), slightly ready (2) and Not ready (1), Section C contains a 10-item list of AI to check for their use by pre-service Biology teachers for instructional delivery. The Likert-type response modes of Always (1), Sometimes (2), Rarely (3), and Never (4) were adopted for this section.

The research instrument was subjected to face and content validity. The research instrument was given to the researcher's supervisor, two experts in Educational Technology, and one expert in tests and measurements, at the Faculty of Education, Al-Hikmah University, Ilorin. They checked whether the instrument measured what it was supposed to measure, the clarity of the items and the arrangements of the items in the instrument were also checked. The suggestions of the experts were considered before the items of the research instrument were put together.

The reliability of the questionnaire was assessed, and the instrument was administered by the researcher to 50 pre-service Biology teachers in an institution not sampled for the actual study in the study population area. The instrument was administered once to the sampled pre-service Biology teachers. For reliability, the internal consistency of the instrument was determined using Cronbach's Alpha. The reliability index for Section B on Accessibility was 0.77; for Section C on Readiness was 0.83; while a value of 0.85 was obtained for Section D on Use of AI. An overall alpha value of 0.82 was obtained for the reliability of the instrument.

The researcher collected a letter of introduction from the Head of the Department of Science Education, Al-Hikmah University, Ilorin. Then, the researcher personally visited the institutions here in Kwara State with printed copies of the questionnaire. Also, the Google form link was sent to the employed research assistants in other states where the study was carried out. Permission was sought from authorities of the sampled institutions on the need to allow their students to participate in the collection of the research data. Copies of the informed consent form were attached to the printed questionnaire and the distributed Google forms for the students to indicate their willingness to participate voluntarily in the study. Pre-service teachers who participated in this research work were not exposed to any form of risk as it was made known to them that their responses would be treated confidentially and their identities would not be revealed to anyone. A plagiarism test was carried out to ascertain that this work is not an existing work written by another researcher. The researcher assured the participating pre-service teachers that their efforts and contributions would be treated confidentially and for this study only. Printed questionnaires were distributed, a link to the Google Form questionnaires was sent to the selected students and their responses were retrieved immediately for data analysis.

However, out of the total number of distributed printed copies of the questionnaire and ones administered totalling 792, the total number of responses retrieved and found usable for data analysis was 695, indicating 87.63% of retrieved and usable questionnaire copies. This is above the number of respondents suggested in the sample size table by Cohen et al. (2018). The ethical issues such as maintaining the privacy and confidentiality of student information which may have arisen when carrying out this research were addressed as follows: The respondents were allowed to voluntarily participate in this study to conform with the ethical practice of research. Appropriate steps were taken to adhere strictly to the ethical guidelines to uphold respondents' privacy, confidentiality, dignity, rights and anonymity.

Frequency, percentages, mean score and the t-test statistical analysis were used to analyse the data. The administered questionnaires were collated, and the responses from the Google form were also

downloaded and analysed using SPSS version 25. Meanwhile, demographic information was converted to frequency and percentages to show the distribution of respondents. Research questions 1-4 were answered with the mean scores. This means that the data analysis techniques was descriptive statistic. Simple percentages, frequency counts, and mean scores were used.

Results and Interpretations

Research Question 1: To what extent do pre-service Biology teachers have access to AI in North Central, Nigeria?

Table 1: Access to AI in North Central, Nigeria

Item	NAC	PAC	AC	VAC	$\bar{x}$
	F %	F %	F %	F %	
Artificial intelligence (AI)	32 (4.60%)	60 (8.63%)	182 (26.19%)	421 (60.58%)	3.43

The result presented in Table 1 shows the level of access of pre-service Biology teachers to Artificial Intelligence (AI) technologies in North Central Nigeria. The findings indicate that pre-service Biology teachers have a high level of access to AI technologies, as reflected by the overall mean score of 3.43. Based on the decision criterion, the mean value suggests that AI is accessible to the majority of the respondents. The distribution of responses revealed that 421 respondents (60.58%) indicated that they had very high access (VAC) to AI technologies, while 182 respondents (26.19%) reported that they had access (AC) to AI technologies. This implies that a total of 603 respondents (86.77%) perceived that they had either access or very high access to AI tools. In contrast, 60 respondents (8.63%) reported partial access (PAC), while 32 respondents (4.60%) indicated no access (NAC) to AI technologies.

The finding suggests that AI technologies have gained considerable availability among pre-service Biology teachers in North Central Nigeria. The high level of access may be associated with the increasing adoption of internet-enabled mobile devices, availability of online AI platforms, and growing awareness of generative AI applications that can be accessed through smartphones and personal computers. This indicates that most pre-service Biology teachers are exposed to AI technologies, providing them with opportunities to explore and develop familiarity with AI-based tools that can support instructional activities. The result further implies that accessibility may no longer constitute a major obstacle to AI adoption among the majority of pre-service Biology teachers in the study area. Having access to AI technologies provides an important foundation for developing AI competence, confidence, and readiness for instructional integration. Since exposure and interaction with technology often influence users' familiarity and acceptance, increased access may enhance pre-service teachers' ability to incorporate AI tools into lesson planning, instructional material development, assessment preparation, and classroom delivery.

However, the finding that 13.23% of respondents reported either partial or no access to AI technologies indicates that disparities in access still exist among some pre-service Biology

teachers. These limitations may be related to factors such as inadequate digital infrastructure, poor internet connectivity, inability to afford AI-enabled devices, limited access to advanced AI applications, or differences in institutional technology support. Therefore, although the overall accessibility level is high, efforts are still required to ensure equal access to AI technologies for all pre-service teachers.

Research Question 2: What is the level of Readiness of pre-service Biology teachers to AI for instruction?

Table 2: Level of Readiness of pre-service Biology teachers to AI for instruction

Item	HR	MR	SR	NR	$\bar{x}$
Artificial intelligence (AI)	10 (1.44%)	29 (4.17%)	209 (30.07%)	447 (64.32%)	3.57

The result presented in Table 2 shows the level of readiness of pre-service Biology teachers to use Artificial Intelligence (AI) for instructional purposes in North Central Nigeria. The findings reveal that pre-service Biology teachers demonstrated a high level of readiness to use AI for instruction, as indicated by the mean score of 3.57. This suggests that the respondents possess a considerable level of preparedness, willingness, and confidence towards integrating AI technologies into their instructional practices. The distribution of responses indicates that 447 respondents (64.32%) reported a very high level of readiness (NR) to use AI for instruction, while 209 respondents (30.07%) indicated a high level of readiness (SR). Collectively, 656 respondents (94.39%) demonstrated either high or very high readiness towards the use of AI for instructional delivery. On the other hand, 29 respondents (4.17%) reported a moderate level of readiness (MR), while only 10 respondents (1.44%) indicated a low level of readiness (HR).

The result implies that the majority of pre-service Biology teachers are prepared and willing to incorporate AI technologies into teaching and learning activities. The high readiness level may be associated with increased exposure to digital technologies, growing awareness of AI applications, and the widespread use of AI-powered tools such as generative AI platforms for academic and professional activities. This level of readiness suggests that pre-service Biology teachers have developed positive dispositions towards AI and may be willing to explore its applications for lesson preparation, instructional material development, assessment construction, learner support, and classroom engagement. Furthermore, the finding indicates that readiness to use AI among pre-service Biology teachers extends beyond mere awareness of AI technologies. A high readiness level suggests that respondents may possess the confidence and motivation required to experiment with AI tools for instructional purposes. Since readiness is an important precursor to technology adoption, the result implies that pre-service Biology teachers in North Central Nigeria have the potential to become effective users of AI-enabled instructional approaches when adequate institutional support, training, and resources are provided.

However, the presence of respondents with moderate or low readiness (5.61%) indicates that some pre-service Biology teachers may still experience challenges in adopting AI for instructional purposes. These challenges may include limited knowledge of AI applications, inadequate practical experience, uncertainty about ethical issues associated with AI use, insufficient

pedagogical understanding of AI integration, or limited opportunities for hands-on training. Therefore, while overall readiness is high, continuous AI-related capacity-building programmes remain necessary to ensure that all pre-service teachers develop the competence required for effective instructional integration of AI.

The result also suggests that readiness alone may not automatically translate into actual classroom utilisation of AI. Although pre-service Biology teachers demonstrate willingness and preparedness, successful instructional integration requires complementary factors such as access to AI technologies, institutional encouragement, technical support, and opportunities to practise AI-supported teaching strategies during teacher education programmes.

Research Question 3:

What is the level of use of AI for instruction by pre-service Biology teachers for instructional delivery?

Table 3*: *Level of use of AI for instruction by pre-service Biology teachers for instructional delivery?

S/N	Item	N		R		S		A		Mean
		F	%	F	%	F	%	F	%	
1	I use AI to search for relevant content in Biology	40	5.76	61	8.78	202	29.06	392	56.40	3.36
2	I use AI to prepare Biology lesson notes	67	9.64	84	12.09	314	45.18	230	33.09	3.02
3	I use AI to present lessons in Biology classes	79	11.37	94	13.53	254	36.55	268	38.56	3.02
4	I use AI as a teaching resource during Biology lessons	72	10.36	106	15.25	248	35.68	269	38.71	3.03
5	I use AI to set questions for assessment purposes	75	10.79	93	13.38	254	36.55	273	39.28	3.04
6	I keep student assessment records and other information using AI	84	12.09	99	14.24	249	35.83	263	37.84	2.99
7	I design educational packages using AI	101	14.53	93	13.38	235	33.81	266	38.27	2.96
8	I analyse data to improve my practice using AI	92	13.24	128	18.42	208	29.93	267	38.42	2.94
9	I use AI when preparing online assessments for my students	89	12.81	96	13.81	249	35.83	261	37.55	2.98
10	I use AI to track student attendance in my Biology classes	125	17.99	109	15.68	220	31.65	241	34.68	2.83
	Average mean									**3.02**

Note: F= frequency, %= percentage, N= never, R=rearly, S=sometimes, A=always

The result presented in Table 3 shows the level of use of Artificial Intelligence (AI) by pre-service Biology teachers for instructional delivery. The findings indicate that pre-service Biology teachers demonstrated a moderate level of AI use for instructional purposes, with an overall mean score of 3.02. This implies that although pre-service Biology teachers utilise AI tools for various instructional activities, the frequency and depth of use are not yet at an optimal level.

The item-by-item analysis revealed that the highest level of AI usage was recorded for using AI to search for relevant Biology content, with a mean score of 3.36. Specifically, 392 respondents (56.40%) indicated that they always use AI for searching relevant Biology content, while 202 respondents (29.06%) reported occasional use. This suggests that AI is increasingly being used as an information retrieval and knowledge-support tool among pre-service Biology teachers. The finding indicates that respondents rely on AI mainly for accessing Biology-related information, explanations, examples, and supplementary instructional materials.

The use of AI for preparing Biology lesson notes recorded a mean score of 3.02, indicating a moderate level of utilisation. The result showed that 230 respondents (33.09%) always use AI for preparing lesson notes, while 314 respondents (45.18%) use it sometimes. This suggests that although AI has become a useful resource for lesson preparation, many pre-service Biology teachers may still depend on conventional approaches or combine AI-generated materials with traditional methods.

Similarly, the use of AI for presenting Biology lessons in classes recorded a mean score of 3.02. The findings revealed that 268 respondents (38.56%) always use AI for lesson presentation, while 254 respondents (36.55%) use it sometimes. This indicates that AI is gradually being incorporated into classroom delivery; however, its application as a direct instructional support tool remains moderate among pre-service Biology teachers.

The use of AI as a teaching resource during Biology lessons had a mean score of 3.03, with 269 respondents (38.71%) indicating always use and 248 respondents (35.68%) indicating occasional use. This suggests that pre-service Biology teachers are beginning to recognise AI as a supplementary instructional resource for improving explanations, providing examples, and enhancing students' learning experiences.

Regarding the use of AI for setting assessment questions, the result recorded a mean score of 3.04. The findings showed that 273 respondents (39.28%) always use AI for assessment purposes, while 254 respondents (36.55%) use it sometimes. This implies that AI is increasingly being adopted for assessment preparation, particularly in generating questions and supporting assessment design.

However, lower levels of AI utilisation were observed in more advanced instructional applications. For instance, the use of AI for keeping student assessment records and other information recorded a mean score of 2.99, while designing educational packages using AI recorded 2.96. Similarly, the use of AI for analysing data to improve teaching practice had a mean score of 2.94, and preparing online assessments recorded 2.98. These findings suggest that pre-service Biology teachers have limited engagement with AI applications involving data management, analytics, instructional design, and technology-enhanced assessment systems.

The lowest level of AI use was observed in the item "I use AI to track student attendance in my Biology classes," which recorded a mean score of 2.83. The result showed that only 241 respondents (34.68%) always used AI for attendance tracking, while 125 respondents (17.99%) indicated that they never used AI for this purpose. This suggests that AI-supported classroom management applications are less commonly utilised by pre-service Biology teachers, possibly due to limited exposure to specialised educational AI platforms, inadequate institutional support, or lack of practical experience with AI-based classroom management tools.

The overall mean score of 3.02 indicates that pre-service Biology teachers have moved beyond awareness of AI technologies and are engaging with AI for instructional purposes; however, their usage is largely concentrated on basic applications such as information searching, lesson preparation, and resource development. More complex applications, including instructional analytics, automated record management, personalised learning support, and AI-driven classroom management, remain less utilised.

The finding implies that while pre-service Biology teachers demonstrate willingness and readiness to use AI for instruction, their actual application of AI is still developing. This suggests the existence of a possible gap between AI readiness and practical instructional utilisation. Therefore, teacher education programmes should provide more hands-on opportunities that expose pre-service Biology teachers to diverse AI applications beyond content generation, including AI-supported assessment, data analysis, adaptive learning, virtual simulations, and classroom management.

Discussions

The findings of this study revealed that pre-service Biology teachers in North Central Nigeria have high access to AI technologies (mean = 3.43), high readiness to use AI for instruction (mean = 3.57), and moderate AI utilisation for instructional delivery (mean = 3.02). The high level of access suggests that AI technologies are becoming increasingly available within teacher education environments, providing opportunities for pre-service teachers to use AI tools for lesson preparation, content exploration, instructional material development, and assessment creation. This finding supports Miao and Cukurova (2024), who identified access to AI technologies as essential for developing teachers' AI competencies. Similarly, LeCun (2022) noted that increased availability of digital resources and AI platforms promotes experimentation and innovation among teachers and learners. The finding also agrees with Adomi and Kpangban (2010) and Agbo (2020), who reported gradual improvements in technology availability within Nigerian educational institutions.

However, the result differs from Mtebe and Raisamo (2014) and Alimi et al. (2024), who highlighted persistent challenges related to infrastructure, institutional support, and unequal access to digital technologies in developing contexts. The higher access level observed in the present study may be attributed to the rapid expansion of mobile technology and web-based AI applications, which allow users to access AI tools through smartphones and personal devices. Nevertheless, access alone does not guarantee effective use, as factors such as digital skills, internet affordability, and institutional support remain important for meaningful AI integration.

The study further showed that pre-service Biology teachers have a high level of readiness to use AI for instructional purposes. This indicates positive attitudes, confidence, and willingness to integrate AI into Biology teaching. The finding agrees with Miao and Cukurova (2024), who explained that AI readiness involves technical competence, ethical understanding, confidence, and the ability to apply AI pedagogically. It also supports Schina et al. (2021) and Viberg et al. (2023), who found that exposure, confidence, and positive perceptions of technology influence teachers' willingness to adopt emerging technologies. However, the result contrasts with Ayanwale et al. (2024) and Hennessy et al. (2022), who reported that inadequate training and limited infrastructure reduce teachers' preparedness for technology integration. The higher readiness observed in this

study may be linked to increased exposure of young adults to generative AI tools through academic activities and online platforms. However, readiness must extend beyond familiarity with AI tools to include pedagogical knowledge, ethical awareness, and effective classroom application, as emphasised by Koehler and Mishra (2009).

Despite high access and readiness, the findings showed that actual AI use for instructional delivery remains moderate. Pre-service Biology teachers mainly used AI for searching content, preparing lesson notes, developing instructional materials, and generating assessment questions, while advanced applications such as learning analytics, personalised instruction, and classroom management were less common. This finding agrees with Celik et al. (2022) and Martin et al. (2020), who reported that teachers often use AI and digital technologies for basic support functions rather than fully integrated instructional practices. It also supports Holden and Rada (2011), who noted that perceived usefulness and ease of use influence technology adoption, and Bolaji and Adeoye (2022), who highlighted the importance of accessibility and institutional support in technology utilisation.

The moderate level of AI use differs from Gloria and Oluwadara (2015), who reported strong intentions among Nigerian pre-service teachers to use digital technologies, and from Foulger et al. (2013), who argued that teacher education should develop strong technology integration competencies. The difference between high readiness and moderate utilisation suggests that willingness alone does not automatically translate into effective classroom application. In line with Davis' (1989) technology acceptance model, actual AI use depends not only on perceived usefulness and ease of use but also on training, practical exposure, and institutional support. Therefore, while the findings indicate encouraging progress in AI accessibility and readiness among pre-service Biology teachers, teacher education programmes should provide structured AI training and practical opportunities to ensure effective and sustainable integration of AI into Biology instruction.

Conclusion

The study concludes that pre-service Biology teachers in North Central Nigeria have high access to Artificial Intelligence (AI) technologies and demonstrate a high level of readiness to use AI for instructional purposes. The findings indicate that AI technologies are increasingly available to pre-service teachers, providing opportunities for lesson preparation, content exploration, instructional material development, and assessment support. Similarly, their high level of readiness suggests positive attitudes, confidence, and willingness to integrate AI into Biology teaching. However, despite high access and readiness, the actual use of AI for instructional delivery remains at a moderate level, with utilisation largely limited to basic applications such as searching for Biology content, preparing lesson notes, developing teaching resources, and generating assessment questions, while advanced applications such as data analysis, personalised learning, classroom management, and AI-supported assessment systems are less utilised. The study therefore concludes that although the foundation for AI integration among pre-service Biology teachers is promising, there is a need for structured AI training, practical exposure, institutional support, and improved opportunities for hands-on application to transform access and readiness into effective and sustainable instructional use of AI in Biology education. The following recommendations were made:

1. Since pre-service Biology teachers demonstrated a high level of access to AI technologies, teacher education institutions should strengthen and sustain access by providing reliable AI-enabled facilities, internet connectivity, and institutional support to ensure that all pre-service teachers, including those with limited access, can benefit from AI resources for instructional purposes.
2. In view of the high level of readiness of pre-service Biology teachers to use AI for instruction, teacher education programmes should introduce structured AI training and capacity-building programmes that focus on developing practical skills, ethical awareness, and pedagogical knowledge required for effective integration of AI into Biology teaching.
3. Since the actual use of AI for instructional delivery was found to be moderate and mainly limited to basic applications, teacher education institutions should provide more hands-on opportunities for pre-service Biology teachers to practise advanced AI applications, such as AI-supported assessment, instructional analytics, personalised learning, virtual simulations, and classroom management tools, in order to bridge the gap between AI readiness and effective instructional utilisation.

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ACCESS RATE AND PERCEIVED USEFULNESS OF ONLINE LEARNING PLATFORMS AMONG UNDERGRADUATES IN SELECTED PUBLIC UNIVERSITIES IN KWARA STATE

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Abstract

This research explored the usability and access rates of online learning platforms among undergraduate students at public universities in Kwara State, Nigeria. The objective was to identify the most utilised platforms, evaluate levels of accessibility, gauge perceived usefulness, and assess student engagement. Using a descriptive survey approach, data were gathered from 300 undergraduates through a validated questionnaire and analysed using descriptive statistics. Results indicated that WhatsApp was the most commonly used platform (23.3%), followed by Telegram and Zoom. While access to devices was generally high, significant infrastructural challenges included inconsistent electricity supply (mean=1.95) and high internet costs (mean=2.45), leading to a moderate overall accessibility rating (mean=2.71). Students rated the platforms as highly beneficial (mean=3.29) for ease of use and resource availability, although engagement levels were moderate (mean=2.81) and mostly passive. The study concludes that although students hold favourable views on these platforms, infrastructural challenges severely limit their effective use.

Recommendations include increased institutional investments in reliable power and internet infrastructure and training in pedagogical methods to improve interactive engagement in online settings.

Keywords: Online learning platforms, accessibility, perceived usefulness, academic engagement, undergraduates.

Introduction

The proliferation of technology in education is exponentially linked to the broad use of online educational platforms, which has resulted in a series of possessing great implications for many facets and aspects of higher education. Online learning or internet-based education has been adopted in various dimensions due to its flexibility and versatile opportunities for different target groups. Conversely, the COVID-19 pandemic only sped this process, forcing institutions to quickly shift instruction online while showcasing both the promise and growing pains associated with such a pedagogical practice. Dhawan, (2020) stated that the advent of digital technology has revolutionised the educational landscape, particularly in higher education. Therefore, Online learning platforms have emerged as essential tools for delivering educational content, offering flexibility and accessibility to students worldwide.

Literally, it's expressed that Online Learning Platforms as a wide concept that encompasses the collaborative use of the internet and other essential learning materials, tools, facilities and resources for teaching purposes. It could be defined as the combination of the internet and multimedia technologies to ease and enhance the teaching-learning processes. Abdulmumin et al. (2025) stated that Online education enables teachers and students to set their own learning pace, and added flexibility of setting a schedule that fits everyone's agenda. As a result, using an online educational platform allows for a better balance of work and studies, so there's no need to give anything up. Easy access, interaction, flexibility, as well as the use of social media communication all form the core considerations of the online learning platforms. However, in Nigeria, where the conventional system of education has its challenges in its system, embracing online learning platforms is an added advantage in improving access and quality of education (Ogunode et al., 2021). Therefore, the usefulness of these platforms depends on a number of issues, such as students' access to technology and their views regarding the importance of the platforms to learning.

Access to online learning platforms is a critical factor influencing the effectiveness of digital education. According to Bedenlier et al. (2020) Access encompasses not only the availability of technology but also the skills and resources required to utilise it effectively. A study by Huda, (2024) demonstrated that students from lower socio-economic backgrounds faced greater barriers in accessing online learning platforms due to inadequate technology and internet connectivity. Likewise stressed that socio-economic status significantly impacts students' access to online resources. A report by the Matemba & Mwandosya, (2023) highlighted that only a fraction of the population has reliable internet access, which poses a significant challenge for undergraduates seeking to engage with online learning platforms.

Bansah & Agyei (2022) discovered that learners significantly depended on social media and messaging platforms such as WhatsApp for educational purposes because of their minimal data usage, convenience, and simplicity for group communication. Kauffman (2018) in "A review of predictive factors of student success in and satisfaction with online learning" consistently

identified that the interaction between students and instructors is among the key factors influencing satisfaction and success, even though it is frequently the area where online courses fall short. Sambo et al. (2022) explored the difficulties faced by undergraduates in South-West Nigeria regarding the adoption of e-learning, highlighting unstable power supply and high cost of internet data as the two primary obstacles to successful online education. They concluded that although there is a high level of mobile device ownership, these essential infrastructural and economic factors significantly hinder accessibility, reflecting the "notable gap" between device ownership and effective use mentioned in your analysis.

Online delivery of knowledge is an essential aspect that defines the feasibility of effective knowledge dissemination through educational technology tools. Access, therefore, refers not only to technology availability but also to the technology skills and resources needed in order to use technology. Using quantitative data collected from students at a massive university in West Texas, Huda, (2024) presented research that highlighted several challenges low SES students face in accessing online learning platforms because of poor technology and internet connectivity. Socio-economic status was also emphasised by Likewise that it plays a huge role in determining the amount of time that the students spend and the kind of resources available for them online. The Matemba & Mwandosya, (2023) indicated that the internet penetration rate per population is very low, and this is a big challenge to undergraduates seeking help from online platforms.

The modelling and acceptability of any online learning platforms ought to be aligned with the Technology Acceptance Model (TAM) system, which states that: the success of any new technology adoption is based on positive attitudes towards these two factors: Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) (Alsharida et al., 2021). Therefore, the perception of online learning as a viable educational alternative varies among students, influenced by their experiences and societal attitudes toward technology (Salah & Ayyash, 2025) While some students appreciate the convenience and resource availability associated with online platforms, others express scepticism regarding the effectiveness of online learning compared to traditional classroom settings (Lazim & Ismail, 2021) Understanding these perceptions is crucial, as they directly affect students' motivation and engagement levels and overall satisfaction with their learning experiences.

The modelling and acceptability of any online learning platforms ought to be aligned with the Technology Acceptance Model (TAM) system, which states that Optimism when it comes to these two factors has been found to determine the rate of success of any new technology adoption, and they are Perceived Usefulness (PU) and perceived ease of use (PEOU). Hence, the acceptability of distance learning as an option in education differs proportionally with students' experiences and the perception of technology by society (Alsharida et al., 2021). Some of them regard flexibility in terms of resources and access brought by the means of types of learning preferred to the online platforms, while others discuss the effectiveness of online learning compared to classroom learning (Mohamed et al., 2024). Knowledge of these perceptions remains pertinent since it is determinant of students' attitudes and their willingness to participate in learning processes, and broad satisfaction with the learning experience.

Abdulmumin et al. (2025) revealed that undergraduate students in Kwara State perceived the usefulness of online learning platforms positively. This perception likely stems from their experience during the COVID-19 pandemic, where OLPs enabled continued academic engagement despite physical school closures. Students believe OLPs help improve learning

outcomes because they offer flexibility, access to study materials, and opportunities for collaboration.

Purpose of the Study

The main purpose of the research is to examine the Access Rate and Perceived Usefulness of Online Learning Platforms among Undergraduates in Selected Public Universities in Kwara State. Specifically, the research shall:

1. Identify the commonly used Online Learning Platforms among undergraduates in selected public universities in Kwara State.
2. Examine the accessibility levels of Online Learning Platforms among undergraduates in selected public universities in Kwara State.
3. Determine the perceived usefulness of Online Learning Platforms among undergraduates in the selected public universities in Kwara State
4. Find out the engagement levels while using Online Learning Platforms among undergraduates in the selected public universities in Kwara state.
5. Examine if the accessibility level of Online Learning Platforms influences undergraduate perceived usefulness
6. Find out if the undergraduates' perceived usefulness of Online Learning Platforms influences their academic motivations and engagement levels

Research Question

1. What are the commonly used Online Learning Platforms among undergraduates in selected public universities in Kwara State?
2. What is the accessibility level of Online Learning Platforms among undergraduates in selected public universities in Kwara state?
3. What is the perceived usefulness of Online Learning Platforms among undergraduates of the selected public universities in Kwara state?
4. What is the level of engagement of undergraduates in the selected public universities while using Online Learning Platforms?

Research Hypothesis

$H0_1$: There is no significant difference between undergraduates' accessibility levels of Online Learning Platforms and their perceived usefulness

$H0_2$: There is no significant difference between undergraduates' perceived usefulness of Online Learning Platforms and their academic engagements

Methodology

This study employed a descriptive research design of the survey type using a quantitative approach, deemed appropriate for obtaining the opinions and experiences of a large number of undergraduate students regarding their access to and perceived usefulness of online learning platforms. The

design enabled a systematic description of the existing conditions without manipulation of variables. The population of the study comprised all undergraduates, while the target population was undergraduates from the faculty of education in the selected public universities in Kwara State. A multi-stage sampling technique was used: first, universities were purposively selected; then departments were stratified to ensure adequate representation; and finally, 300 students were randomly sampled across the strata. A structured questionnaire, which consisted of five sections with 25 items, with a four-point Likert scale ranging from Strongly Agree (4) to Disagree (1). The face and content validity of the instrument were established through expert review in Educational Technology and Measurement, while a pilot study was conducted to test for reliability. The internal consistency of the instrument was determined using Cronbach's Alpha, which yielded a reliability coefficient above the acceptable benchmark of 0.70, confirming its suitability for the study. Data collected were analysed using descriptive statistics (frequency counts, percentages, and mean scores) to answer the research questions, while inferential statistics such as t-test and Analysis of Variance (ANOVA) were employed to test the hypotheses at a 0.05 level of significance. This methodological approach ensured that the study provided both a descriptive account and a statistically robust test of relationships among the variables.

Results and Discussion

Research Question 1: What are the commonly used online learning platforms among undergraduates in selected public universities in Kwara State?

Table 1: Commonly Used Online Learning Platform among Undergraduates in Public Universities

S/N	Items	Frequency (f)	Percentage (%)
1	WhatsApp	70	23.3%
2	Telegram	55	18.3%
3	Zoom	45	15.0%
4	Microsoft Teams	40	13.3%
5	Google Classroom	35	11.7%
6	YouTube	20	6.7%
7	Blackboard	15	5.0%
8	Udemy	10	3.3%
9	Duolingo	5	1.7%
10	Khan Academy	5	1.7%
	Total	**300**	**100%**

Table 1 shows that WhatsApp emerges as the most widely utilised online learning platform among undergraduates in the selected public universities in Kwara State, with 70 respondents (23.3%) acknowledging its use. Following this, Telegram accounts for 18.3% and Zoom for 15.0%, illustrating a strong inclination towards instant messaging and video conferencing tools.

Educational management platforms like Microsoft Teams (13.3%) and Google Classroom (11.7%) are utilised by a smaller, yet still noteworthy, segment of the student population. Other dedicated educational platforms, including YouTube (6.7%), Blackboard (5.0%), Udemy (3.3%), Duolingo (1.7%), and Khan Academy (1.7%), fall significantly behind. This distribution indicates that students prefer platforms that enable straightforward communication and real-time engagement rather than formal Learning Management Systems (LMS), likely due to their accessibility, lower data usage, and user-friendly nature for coordinating with peers and instructors. This aligns with the study of Bansah & Agyei (2022), who discovered that learners significantly depended on social media and messaging platforms such as WhatsApp for educational purposes because of their minimal data usage, convenience, and simplicity for group communication.

Research Question 2: What is the accessibility level of online learning platforms among undergraduates in selected public universities in Kwara State?

Table 2; accessibility level of online learning platforms among undergraduates in selected public universities in Kwara State

S/N	Item Statement	Highly Accessible f (%)	Moderately Accessible f (%)	Slightly Accessible f (%)	Not Accessible f (%)	Mean
1	My level of access to the internet for online learning	60 (20.0%)	150 (50.0%)	70 (23.3%)	20 (6.7%)	2.83
2	My access to a personal laptop/smartphone for online learning	210 (70.0%)	75 (25.0%)	15 (5.0%)	0 (0.0%)	3.65
3	The quality and speed of internet connectivity available to me	45 (15.0%)	105 (35.0%)	120 (40.0%)	30 (10.0%)	2.55
4	My ability to afford data subscriptions for online learning	30 (10.0%)	105 (35.0%)	135 (45.0%)	30 (10.0%)	2.45
5	My access to university-provided e-learning facilities	45 (15.0%)	165 (55.0%)	75 (25.0%)	15 (5.0%)	2.80
6	The stability of the electricity supply for participating in online learning	15 (5.0%)	60 (20.0%)	120 (40.0%)	105 (35.0%)	1.95
7	My ability to access online learning platforms at any time of the day	45 (15.0%)	120 (40.0%)	120 (40.0%)	15 (5.0%)	2.65
8	The general ease with which I can log into and use online learning platforms	60 (20.0%)	135 (45.0%)	90 (30.0%)	15 (5.0%)	2.80
	Average mean					**2.71**

Table 2 presents the overall level of accessibility to online learning platforms for undergraduates at selected public universities in Kwara State is moderate, with an average mean score of 2.71 on a 4-point scale. The analysis shows a notable gap between access to essential hardware and other necessary infrastructure. While the availability of a personal laptop or smartphone is quite high

(Mean=3.65), students encounter significant obstacles regarding the fundamental elements needed to utilise that hardware effectively. The most pressing issue is the unreliable electricity supply, which is the least accessible aspect (Mean=1.95), significantly limiting consistent engagement. Additionally, internet connectivity quality (Mean=2.55) and, importantly, the affordability of data subscriptions (Mean=2.45) are only marginally to moderately accessible, highlighting that both cost and internet reliability are major barriers. Although students report moderate internet access and generally find the platforms user-friendly (both Mean=2.80), the cumulative effects of unstable power, high data costs, and insufficient connectivity considerably restrict their capacity to use online learning platforms at any time (Mean=2.65), ultimately affecting the effectiveness and inclusivity of the online learning experience. This is supported by the findings of Sambo et al. (2022) highlighted unstable power supply and high cost of internet data as the two primary obstacles to successful online education.

Research Question 3: What is the perceived usefulness of online learning platforms among undergraduates of the selected public universities in Kwara State?

Table 3: Perceived usefulness of online learning platforms among undergraduates of the selected public universities in Kwara State

S/N	Item Statement	SA f (%)	A f (%)	D f (%)	SD f (%)	Mean
1	Online learning platforms make it easier for me to access lecture materials at any time.	165 (55.0%)	120 (40.0%)	12 (4.0%)	3 (1.0%)	3.49
2	Online learning platforms enhance my understanding of course content.	120 (40.0%)	135 (45.0%)	30 (10.0%)	15 (5.0%)	3.20
3	Online platforms improve interaction and communication between lecturers and students.	90 (30.0%)	105 (35.0%)	75 (25.0%)	30 (10.0%)	2.85
4	The use of online platforms increases my ability to learn independently.	135 (45.0%)	126 (42.0%)	30 (10.0%)	9 (3.0%)	3.29
5	Online learning platforms help me to collaborate with peers on academic tasks.	150 (50.0%)	114 (38.0%)	27 (9.0%)	9 (3.0%)	3.35
6	Online platforms save time and make learning more convenient.	180 (60.0%)	105 (35.0%)	12 (4.0%)	3 (1.0%)	3.54
7	Using online platforms positively impacts my academic performance.	111 (37.0%)	132 (44.0%)	42 (14.0%)	15 (5.0%)	3.13
8	Online platforms are useful for preparing for tests, assignments, and examinations.	159 (53.0%)	123 (41.0%)	15 (5.0%)	3 (1.0%)	3.46
	Average Mean					**3.29**

Table 3 shows the perceived usefulness of online learning platforms among undergraduates of the selected public universities in Kwara State. The findings reveal that undergraduates generally view online learning platforms as beneficial, supported by a high average mean score of 3.29. The results

strongly emphasise the advantages of convenience and accessibility associated with online learning. This is notably reflected in Item 6, which received the highest mean score (3.54), indicating a clear agreement that online platforms facilitate time savings and increased convenience. Likewise, Item 1 (3.49) and Item 8 (3.46) underscore the perceived benefits of accessing materials "anytime" and their role in academic preparation, respectively. Additionally, students believe that these platforms encourage peer collaboration (Item 5, Mean=3.35) and foster independent learning (Item 4, Mean=3.29). Although still positive, the lowest mean score belongs to Item 3 (2.85), which pertains to interactions with lecturers. This suggests that while students appreciate the platforms' usefulness for content and personal study, the enhancement of direct communication and engagement with instructors is less emphasised, indicating a possible area for pedagogical improvement in the online learning landscape. This aligns with the findings of Abdulmumin et al. (2025), who posited that the perceived usefulness of undergraduate students in Kwara State is positive.

Research Question 4: What is the level of engagement of undergraduates in the selected public universities while using online learning platforms?

Table 4: level of engagement of undergraduates in the selected public universities while using online learning platforms

S/N	Item Statement	Always f (%)	Often f (%)	Rarely f (%)	Never f (%)	Mean
1	I actively participate in online class discussions through chat, audio, or video.	75 (25.0%)	135 (45.0%)	75 (25.0%)	15 (5.0%)	2.90
2	I ask questions or seek clarification from lecturers via online platforms.	30 (10.0%)	90 (30.0%)	135 (45.0%)	45 (15.0%)	2.35
3	I complete and submit assignments through online learning platforms on time.	90 (30.0%)	120 (40.0%)	75 (25.0%)	15 (5.0%)	2.95
4	I collaborate with peers on group tasks or projects using online platforms.	60 (20.0%)	120 (40.0%)	90 (30.0%)	30 (10.0%)	2.70
5	I attend online lectures regularly when organised by my lecturers.	120 (40.0%)	135 (45.0%)	30 (10.0%)	15 (5.0%)	3.20
6	I use discussion forums or group chats to exchange ideas with classmates.	45 (15.0%)	120 (40.0%)	105 (35.0%)	30 (10.0%)	2.60
7	I stay attentive and focused during online lectures or activities.	90 (30.0%)	150 (50.0%)	45 (15.0%)	15 (5.0%)	3.05
8	I review and follow up on learning resources shared on online platforms after classes.	60 (20.0%)	120 (40.0%)	90 (30.0%)	30 (10.0%)	2.70
	Average Mean					**2.81**

According to the information in Table 4, the overall engagement level among undergraduates at the selected public universities when utilising online learning platforms is moderate, with an

average mean score of 2.81. Engagement is robust in aspects of compliance and passive participation. For example, students exhibit high engagement by consistently attending online lectures (Item 5, Mean=3.20) and remaining attentive during these sessions (Item 7, Mean=3.05). They also show a dependable dedication to finishing and submitting assignments punctually (Item 3, Mean=2.95). However, engagement experiences a notable decline when it involves proactive and interactive actions. The lowest level of engagement is noted in seeking clarification from instructors (Item 2, Mean=2.35), indicating a hesitance to initiate discussions with teachers. Likewise, collaborative tasks such as engaging in discussion forums (Item 6, Mean=2.60), collaborating with classmates on group assignments (Item 4, Mean=2.70), and reviewing materials after class (Item 8, Mean=2.70) are performed only sporadically. This trend implies that while students attend and meet required obligations, their engagement often lacks the deeper, interactive characteristics that promote a collaborative and inquiry-driven learning atmosphere. This is in line with Kauffman (2015), who consistently identified that the interaction between students and instructors is among the key factors influencing satisfaction and success, even though it is frequently the area where online courses fall short.

Research hypothesis one: There is no significant difference between undergraduates' accessibility levels of Online Learning Platforms and their perceived usefulness

Table 5*: *One-way ANOVA showing a significant difference in the undergraduates' accessibility levels of Online Learning Platforms and their perceived usefulness

Variables	Sum of Squares	df	Mean Square	F	Sig.	Decision
Between Groups	6.546	2	3.273	4.776	.009	
Within Groups	446.773	298	.685			**Rejected**
Total	453.319	300				

Table 5 presents the one-way ANOVA result showing the difference between undergraduates' accessibility levels of online learning platforms and their perceived usefulness. The result indicates that the calculated F-value is 4.776 with a significance level (p-value) of 0.009, which is less than the 0.05 level of significance. This implies that there is a statistically significant difference in students' perceived usefulness of online learning platforms based on their levels of accessibility. Therefore, the null hypothesis stating that there is no significant difference between undergraduates' accessibility levels of online learning platforms and their perceived usefulness is rejected. This means that students who have greater access to online learning platforms tend to perceive them as more useful for their learning than those with lower access. This finding aligns with Huda (2024), who emphasised that accessibility, comprising internet availability, device ownership, and technological skills, is a key determinant of students' positive perception of online learning. Similarly, Bedenlier et al. (2020) found that students' access to reliable digital infrastructure significantly enhances their engagement and perceived learning outcomes.

Research hypothesis two: There is no significant difference between undergraduates' perceived usefulness of Online Learning Platforms and their academic engagement

Table 6*: *One-way ANOVA showing a significant difference in the undergraduates' perceived usefulness of Online Learning Platforms and their academic engagement

Variables	Sum of Squares	df	Mean Square	F	Sig.	Decision
Between Groups	11.829	2	5.914	10.293	.000	
Within Groups	375.231	298	.575			**Rejected**
Total	385.059	300				

Table 6 presents the one-way ANOVA result examining the relationship between undergraduates' perceived usefulness of online learning platforms and their academic engagement. The analysis shows an F-value of 10.293 with a significance level (p-value) of 0.000, which is less than the 0.05 level of significance. This indicates that there is a statistically significant difference in students' academic engagement based on their perceived usefulness of online learning platforms. Consequently, the null hypothesis stating that there is no significant difference between undergraduates' perceived usefulness of online learning platforms and their academic engagement is rejected. This finding suggests that students who perceive online learning platforms as more useful are likely to exhibit higher levels of academic engagement than those who view them as less useful. This is in line with the study of Alsharida et al. (2021), which posits that perceived usefulness directly influences users' acceptance and behavioural engagement with technology. Likewise, Abdulmumin et al. (2025) confirmed that undergraduates' perception of online learning platforms as beneficial strongly predicts their motivation and active participation in virtual academic activities.

Conclusion

Based on the results of this research, it can be concluded that although undergraduates at selected public universities in Kwara State view online learning platforms as highly beneficial due to their convenience, material accessibility, and encouragement of independent study, the full potential of these resources is greatly hindered by significant infrastructural shortcomings. The overall access to these platforms remains only moderate, marked by a striking discrepancy between high ownership of personal devices and serious issues with unreliable electricity, expensive data, and subpar internet connectivity. As a result, student engagement is often passive and focused on compliance, with minimal levels of interactive and collaborative participation, especially in interactions with instructors. Therefore, for online learning to be effective and inclusive in this environment, strategic measures must simultaneously tackle the fundamental issues of power and internet infrastructure while also promoting teaching methods that improve student-instructor communication.

The study concluded that online learning platforms have become vital instruments in higher education, notably impacting accessibility, learning effectiveness, and student engagement among undergraduates at public universities in Kwara State. Results show that although students have moderate access to online platforms, obstacles such as inconsistent electricity supply, expensive data costs, and inadequate internet connectivity continue to exist. Despite these challenges, students view online learning platforms as extremely beneficial for providing flexibility, convenience, collaboration, and fostering independent learning. However, engagement levels are

mostly moderate, showing more involvement in attending lectures and completing assignments, but less interaction with instructors and fellow students. Additionally, inferential analyses revealed that levels of accessibility have a significant effect on students' perceived usefulness of online platforms, and this perceived usefulness notably impacts academic engagement.

Recommendations

1. Government and university authorities should prioritise and invest in critical infrastructure, including a stable electricity supply and high-speed, affordable internet connectivity on campus and in student residential areas
2. Universities and telecommunications companies should collaborate to provide subsidised data plans or zero-rated educational platforms to alleviate the financial burden of internet data on students.
3. Academic institutions should organise training workshops for both students and lecturers on the effective use of formal Learning Management Systems (LMS) like Google Classroom and Blackboard to enhance their functionality and move beyond reliance on basic communication apps.
4. Lecturers should be encouraged and trained to redesign their online courses to foster interactive and collaborative learning.
5. Universities should ensure that adequate and up-to-date digital learning resources are readily available and easily accessible on their e-learning portals to support independent learning and academic preparation.
6. Institutions should consider adopting a sustainable blended learning model that strategically combines the strengths of online learning (e.g., flexibility, resource access) with face-to-face interactions to address the shortcomings in student-lecturer engagement.

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STAKEHOLDERS' INVOLVEMENT: AN INTERACTIVE MANAGEMENT DASHBOARD FOR MONITORING EDTECH INTERVENTIONS IN KWARA STATE

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ABSTRACT

The increasing adoption of Educational Technology (EdTech) interventions by governments requires effective mechanisms to monitor progress, resource utilization, and outcomes, supporting evidence-based decision-making. However, stakeholders often face challenges related to fragmented data, limited analytical tools, and inadequate visualization systems. Therefore, this study focused on designing and evaluating a management dashboard for stakeholders' monitoring of EdTech interventions in Kwara State. Specifically, the study aimed to design an interactive dashboard, identify essential Key Performance Indicators (KPIs), examine expert validation, and assess the usability and functionality of the developed system. A design-based research approach, complemented with a descriptive survey design, was adopted. The population comprised key stakeholders involved in EdTech interventions, including officials from the Ministry of Education and Human Capital Development, the State Universal Basic Education Board, and the Teaching Service Commission. A purposive sampling technique was used to select 12 participants. A self-structured rating form was developed and validated by three experts, and its reliability was established through pilot testing which yielded 0.910. Simulated datasets representing major EdTech interventions were modeled and visualized using Microsoft Power BI. Data were analyzed using descriptive statistics, including frequency counts, percentages, means, and standard deviations. Findings revealed that stakeholders strongly agreed on the relevance of the identified KPIs for monitoring EdTech interventions. Expert validation results indicated high ratings for clarity, visual appeal, data accuracy, and overall suitability of the dashboard. Additionally, usability and functionality assessments showed that the dashboard was easy to navigate, responsive, and effective in supporting real-time monitoring, reporting, and decision-making. The study concludes that interactive dashboards can significantly enhance EdTech monitoring and recommends their adoption for data-driven educational planning and policy formulation.

Introduction

The use of Educational Technology (EdTech) is one of the most effective and innovative trends that have influenced the education sector in the 21st century. EdTech is a development of the traditional means of teaching using technological resources such as digital devices and platforms, and it not only improves the learning process but also plays a major role in the invention of the

new methods of teaching and learning. This sector initially involved the application of basic electronic devices, projectors, and the like, and has grown and advanced with the application of sophisticated hardware and software, artificial intelligence, and network-dependent teaching and learning platforms (Nsofor et al., 2022).

Kwara State has recorded some major milestones in its efforts to digitize Educational activities, focusing on revamping various aspects of teaching and learning processes in its education system. Some of the basic EdTech interventions being applied in the state are Coding Digital Literacy Programme, Smart School, KwaraLEARN, and the Digital Effective school Programme. These are meant to cover different aspects of improving technological literacy and efficiency in learning. Coding School Program initiated by the Kwara State government aims at providing coding and digital literacy skills for the current students in the public primary and secondary schools. This program has made an impressive impact by training more than 5,500 children from 50 public schools within the state and has put the state at the forefront in digital education in the Nigerian region (Akinyemi, 2025). Kwara Coding and Digital Literacy Program initiated by the Kwara State authorities along with other local organizations aims at training in-school and out-of-school youths on digital literacy skills, beginner programming languages such as Python/Web Development skills, and innovation skills (Ozibo, 2025).

Central to these efforts is KwaraLEARN (Kwara Leading Education Achievement and Reform Now), a state government programme that frames the government's commitment to digitalising classroom processes, providing structured digital learning content, and strengthening teacher support mechanisms in public schools. Official descriptions of KwaraLEARN characterise it as a strategic reform to "transform the current analogue state of teaching and learning to a modern digital learning process" and emphasise investments in devices, curricular content, and teacher capacity building (Secretary, 2022). The intervention equips over 6,000 teachers and headteachers with digital tools, including tablets and smartphones, which deliver structured, standardised lesson plans and facilitate real-time performance monitoring of both pupils and educators (Adisa-Jaji, 2024). This digital pedagogy is designed to standardise instructional delivery, address learning poverty, and ensure that teaching practices are consistent and effective across the entire primary school system.

KwaraLEARN represents a flagship state-wide technology-driven education reform program targeting over 365 primary schools in multiple local government areas. (Adisa-Jaji, 2024) The programme's strategic goal is to significantly improve learning outcomes through continuous support to educators and school leaders, thus fostering personalized and effective instructional delivery. During the launch of the intervention in April 2022, Shehu Raheem Adaramaja, chairman of the Kwara State Universal Basic Education Board (SUBEB), disclosed that the goal of KwaraLEARN is to "improve teaching and learning using data-driven platforms, high-quality learning materials, effective training, and continuous coaching and support for teachers and school administrators." (Adisa-Jaji, 2024)

Smart Schools programs, which act as demonstration sites to ICT-enabled pedagogy and infrastructure, complement the work of KwaraLEARN as an underlining of smart learning environments using the UBEC Model Smart Schools like that in Adeta, Ilorin. These schools demonstrate increased infrastructure and capacity development to involve the incorporation of digital tools and new pedagogical strategies to enhance the level of standard of basic education. The smart school interventions provided by UBEC in Kwara have been known to not only provide

quality learning environments that are capable of enabling digital education (i.e. interactive displays, monitored devices and delivery of digital content) but also demonstrate how ICT can help facilitate day-to-day school operations and learner interaction (UBEC, 2025). According to a report by Kwara Model Smart School, (2025) on these model schools, the programming (events, admissions, and stakeholder engagements) in these model schools is active, which places smart schools as a realistic location in the process of scaling the use of technology in the basic system of education in the state.

Lastly, it is necessary to consider the interventions introduced by Kwara through the national agenda of school effectiveness and standards improvement embodied in the Effective School Programme (advocated by UBEC) (Alice, 2024).. The Effective School Programme offers a conceptual and practice framework of enhancing minimum standards of Universal Basic Education (UBE) provision; and together with state-level investments in EdTech, it presents technology as a facilitating mechanism to producing measurably better learning results and school leadership (Administrator, 2025). Practically, the application of the principles of the effective-school by Kwara has overlapped with the activities of Smart School and KwaraLEARN in order to popularize data-oriented planning and accountability.

Collectively, these EdTech interventions in Kwara State reflect a holistic and multi-layered approach to modernizing education. Meanwhile, across these initiatives, three recurring themes emerge in the literature and government reporting. First, there is a clear policy intent to integrate technology with pedagogical reform: devices and digital content are positioned not merely as hardware but as components of a broader shift toward structured digital pedagogy and teacher support. Second, capacity building for teachers and school administrators is a programme priority; state communications and programme updates repeatedly reference teacher training, digital literacy workshops, and the need for continuous professional development to realise expected gains. Third, preliminary accounts of implementation point to rapid scale-up efforts alongside practical challenges, logistical coordination, reliable data collection, and ensuring sustained use of deployed tools, which suggest the need for monitoring systems that can track implementation fidelity and outcomes over time.

In an educational context, there are three major types of dashboards, including learning analytics dashboards, performance dashboards, and management dashboards. While learning analytics dashboards are learner-centered and focus on student performance, management dashboards provide a macro-view of school systems and interventions, with a particular focus on issues of accountability, policy, and strategic planning. In cases where there is more than one EdTech intervention, such as smart classrooms, digital literacy programs, and large-scale e-learning projects, dashboards serve a crucial purpose, where there is a need for ongoing monitoring and evaluation of these initiatives (Sahin & Ifenthaler, 2021). With EdTech interventions generally involving large-scale, multiple stakeholders, and time-sensitive projects, effective EdTech intervention management requires structured processes that are informed by intervention management principles. EdTech intervention success is not only contingent upon technology quality, but also effective and efficient intervention planning, monitoring, and adaptation according to changing realities (Williams et al., 2020).

The concept of a management dashboard is defined as the application of knowledge, skills, tools, and techniques to meet the specific objectives of technology-based educational initiatives. This includes, but is not limited to, enhancing learning outcomes, enabling and addressing digital tool

accessibility, developing teacher capacity, and addressing a fair allocation of resources. To address the required quality of these program requirements, a project manager would need to work within limitations defined by scope, schedule, or budget, popularly termed as a classic project management challenge (Kerzner, 2018). The essential phases for a management dashboard in a basic, universal business environment, like a traditional school, might follow initiation, planning, execution, control, and closure.

However, Kline et al. (2020) suggested that due to the educational setting, these phases often involve additional complexities such as pedagogy alignment, stakeholder sensitization, technology acceptance, and sustainability planning. In the initiation phase, the stakeholders articulate the problem to be resolved by the EdTech solution, focusing on curriculum improvement or administrative systems. The planning phase starts with resource management, stakeholder analysis, risk assessment, and the definition of success parameters. As per the execution phase, the solution may include technology implementation, training sessions, or logistics, while the monitoring phase utilizes data or site visits for tracking the process.

With regard to the Nigerian situation, EdTech intervention management within schools had long been characterized by challenges of weak monitoring, data reporting, transparency and accountability in particular. Intervention programs were carried out with fervor but lacked the managerial backing and assessment needed for sustainability to take place. Current attempts to respond to this situation would involve the use of interactive management dashboard approaches to oversee state and federal (Universal Basic Education Commission (UBEC)) levels of intervention in schools (Akpan et al., 2022), and other similar approaches. However, widespread adoption remains limited due to infrastructural and human capacity barriers.

The first key management principle when dealing with tech-based interventions in education, known generally as ‘EdTech,’ involves creating a specific scope and aims for the intervention. At this stage, managers of the interventions work with key stakeholders, school administrators, educational planners, and, at times, parents, to determine specific aims of the intervention to be accomplished. This involves setting specific deliverables, specifying performance measurement, and ensuring benefits increase to teaching staff and ‘communities’ of students. Careful determination of specific scope helps to eliminate ‘scope creep,’ which has often been associated with complications arising from tech projects to name but a few (Williams et al., 2020). The principles of an effective management dashboard derive from established human-computer interface frameworks and information-visualisation approaches (Gobert et al., 2023).

The major principles are clarity, relevance, simplicity, timeliness, and interactivity. Clarity simplifies data that are displayed to be easy to understand without needing to employ cognitive load; relevance ensures that the data shown is only that which is relevant to the goal of the users, simplicity focuses on showing minimal information and having a rational interface, timeliness provides data that is real-time, or updated at a regular rate; and interactivity enables users to filter, explore, and customise the information to fit their decision requirements (Eberhard, 2023). Thus, a dashboard created in accordance with the emphasised principles, will help the decision-makers develop the sense of control and confidence, which will subsequently lead to the increased responsiveness of the organisation and data-driven management. Feedback and inclusive decision making are particularly important in the education sector where the ultimate sustainability depends on end-user acceptance (Raadt, 2020).

Education management dashboard, in its functional terms, should carefully combine several elements to facilitate the aggregation of data, their visualization, reporting, and communication. The data aggregation feature is used to bring together data that is available in different forms including school records, monitoring forms, digital learning platforms and survey systems into a single database. The visualization feature converts raw data into simplified forms of display (e.g., charts, trend lines, heat maps) that can be easily interpreted and understood the pattern. The reporting can help users to create a summary or detailed report on key performance indicators (KPIs), and the communication can support people in making decisions together by sharing knowledge with other stakeholders (David, 2021). Good dashboards in an educational setting should therefore not only be used to display the unchanging data but also to aid in taking action and contemplation.

Dashboards, in particular, in EdTech monitoring, were to be utilized to monitor such variables as the devices deployment, involvement of teachers in digital training, use of resources by students, and the outcome of learning performance (Hernández-Campos et al., 2025). As an illustration, a study conducted by (Kaliisa et al., 2024) noted that properly developed dashboards enhance accountability and transparency through the provision of real-time data of the intervention. It is specifically applied to such a context as at Kwara State multiple EdTech interventions such as state-led smart schools, digital literacy centres and massive interventions of deploying devices all run at once and demand centralized monitoring in order to maintain coherence and sustainability.

Teamwork and interaction are also enhanced by intervention management tools, which have real-time chat and forums as well as document co-edits. These characteristics dismantle silos among various stakeholders, promote the process of sharing best practices, and enable the collective distribution of problems. These digital features are also indicative of the inherent collaborative culture of educational settings, which supports the transfer of ownership and expansion of innovations on a school or district-wide level (Raadt, 2020)To succeed in a project, monitoring and evaluation is essential. The analytics and dashboards can be used to offer real-time control over the status of the projects, as well as indicate dangerous activities, and make decisions based on the data. These insights allow school leaders and project managers to quickly reallocate resources and strategy to meet arising challenges to ensure projects stay on course and the desired educational outcomes are attained (Standford, 2024). Raadt, (2020) suggested that the life cycle of EdTech interventions usually follows five phases namely research and initiation, design, development, implementation, and evaluation. In the course of research and initiation, needs are determined, and the viability of interventions is identified. During the design phase, technical and pedagogical requirements are stated. Development involves bringing the project into life by configuring and testing it and implementation by deploying and training users. The last step, evaluation, brings the interventions to a close by conducting a serious evaluation of KPIs and the lessons learned and adding them as part of future innovations.

The implementation of Educational Technology (EdTech) interventions is a collaborative process, as it involves a variety of stakeholders whose roles, responsibilities, and engagement directly impact the outcomes of these interventions. EdTech stakeholders refer to other individuals, groups, educational institutions and agencies that influence or are influenced by the implementation and usage of technology in educational institutions. They play a vital role in the initiation and implementation process as well as the ongoing monitoring and evaluation of the project performance (Malinina et al., 2025). The stakeholder involvement enables successful interventions which have a foundation in local needs, that are culturally acceptable, and technically viable. Hart,

(2023) argues that a major cause of failure of many interventions in Sub-Saharan Africa is the absence of coordinated stakeholder engagement, particularly at the grassroots where interventions are being executed.

EdTech has a broad understanding of the term stakeholder, by considering individuals and groups of people with different levels of influence, responsibility, and interest in the project results. Stakeholders within the school can be the school administrators, educational planners, project managers and IT personnel. On the outside, they include instructional designers, students, parents, community and policymakers, donors and technology providers, as well as regulatory agencies. Both groups also lend a different lens to the project and add insight into the needs, expectations, and contextual nuances (Canton, 2021). Engagement of the stakeholders at an early stage during the ideation and conceptualization phase is key to the success of the intervention. During this stage, designers, including engineers and content developers, engage with users, sponsors, schools, and policymakers in order to make sure that the suggested EdTech solution meets the realities of operations and an overall educational aim. This proactive consultation is supportive of bringing up real-life insights clarifying expectations, and this brings about some initial buy-in by all the affected parties.

Stakeholders have one of the fundamental functions of contributing to the monitoring and evaluation (M&E). The stakeholders are in a better position when actively involved in M&E processes, including dashboard use, reporting, and feedback mechanisms, to identify the gaps in the project, respond to arising challenges, and create accountability. The participatory tools include digital dashboards where in real-time the stakeholders can track resource allocation, the performance of the students, and the infrastructure development (Ika & Pinto, 2022). Capacity building is another critical stakeholder engagement element. Teachers, as being in the front line of the implementation of EdTech, can often need specially designed training and continuous support to use digital tools in the classroom successfully. In the absence of this capacity, even highly technological interventions might not be converted to better teaching and learning (EvalCommunity, 2023). On the same note, administrators and policymakers must be taught how to interpret data available in the dashboard and how to use the insights in making decisions.

The stakeholder is also an important part of sustainability and local ownership of EdTech interventions. The communities will be more likely to consider the project as theirs when they are considered in the planning and implementation process, and hence, increase long-term commitment and minimize reliance on external actors. The use of participatory schemes in school architecture projects has been more effective in Kwara State compared to top-down schemes (Stahl et al., 2017). When applied to EdTech, it implies that the local stakeholders are involved in the development of dashboards, choice of KPI, and feedback components. Besides, the active participation of stakeholders in monitoring directly leads to better transparency and accountability.

Sharing and making project data, progress, and challenges available to the parties concerned will create a sense of trust and minimize the possibility of mismanagement or miscommunication (Gümüsay & Reinecke, 2024). Such an overall check gives the stakeholders an ability to make the implementing bodies accountable in terms of resource use and achievement of targets. Specifically, funding partners are becoming more and more obsessed with the presence of strong monitoring frameworks in order to make their investments produce visible outcomes, and that is where stakeholder-accessible monitoring is essential to attracting and retaining financial resources (Malinina et al., 2025)

Furthermore, transparency and equal distribution of resources are encouraged by the involvement of all stakeholders. A dynamic dashboard, such as one that indicates the distribution of devices or teacher training in real time (by school) can make it possible to ensure that underserved regions are not neglected. It also enables the donor agencies and government officials to authenticate field reports and detain project actors (Hennessy et al., 2021). Monitoring as a collaborative process is also easy to achieve due to the prevalence of stakeholders, which helps in the early identification of problems and the management process being adaptive. The various perspectives will be able to uncover the problems that would otherwise have been missed by a centralised intervention team. As an example, a teacher could report on certain technical issues or teaching-related difficulties that, in turn, could be resolved at the earliest stage, which would avoid the barriers to extensive adoption. This collective intelligence enables prompt interventions, corrections of the course, and adaptive strategies, which is to be important to maneuver the frequently unpredictable complexities of EdTech implementation (Hennessy et al., 2021). It makes monitoring more of a dynamic feedback loop that informs on the continuous improvement, rather than just a reporting exercise.

Nonetheless, Temitope et al., (2024) asserted that the effective stakeholder involvement cannot be facilitated without issues. They usually consist of information asymmetries, where various stakeholders have unequal access to, or knowledge about, intervention data; divergent interests, which may cause conflicts over the allocation of resources or the strategy to follow; and communication barriers caused by different technical capabilities, language differences or absence of standard reporting systems. The logistic limitations, in such cases as Kwara State, the lack of digital literacy among some stakeholders, and well-established bureaucratic standards may also make collaborative monitoring more complicated. Also, Jeremiah (2019), submitted that there are bureaucratic inefficiencies, political interference, and a lack of communication between players in EdTech interventions in Nigeria. In many instances, the federal-level project planners have no connection with the local government or school-level implementers. To close this divide, it is necessary to map all its stakeholders deliberately, have open communication channels, and user-friendly monitoring systems that would be accessible to both technical and non-technical users (Jeremiah, 2019).

Purpose of the Study

The main purpose of this study was to design and evaluate an interactive management dashboard for stakeholders' monitoring of Educational Technology interventions in Kwara State.
Specifically, the study aims to:

1. design an interactive management dashboard for monitoring Educational Technology interventions;
2. examine the usability of the designed interactive management dashboard for monitoring EdTech interventions; and
3. assess the functionality of the designed interactive management dashboard in enhancing stakeholders to monitor EdTech interventions in Kwara State.

Research Question

The following questions were answered during the study.

1. What are the processes of designing an interactive management dashboard to monitor Educational Technology interventions?
2. How usable is the designed interactive management dashboard for monitoring EdTech interventions in Kwara State?
3. What is the functionality of the designed interactive management dashboard in enhancing stakeholders to monitor EdTech interventions in Kwara State?

Methodology

This study adopted a Design and Development Research (DDR) method, with a quantitative Human-Centered Design approach to provide a comprehensive understanding of how data-driven influences the effectiveness of EdTech initiatives. This design method is suitable as it is an iterative research approach used to design, implement, revise interventions, and refine practical solutions to real-world problems in education. The choice of DDR is particularly appropriate for this study, as the study designed an interactive management dashboard and evaluated its performance with stakeholders involved in EdTech interventions. The population of this study comprised all key stakeholders involved in the planning and monitoring of EdTech interventions in Kwara State. The target population of this study was government officials, these include officials from the Kwara State Ministry of Education and Human Capital Development, the State Universal Basic Education Board (SUBEB), and the Teaching Service Commission (TESCOM), as the personnels that are responsible for overseeing EdTech interventions. These stakeholders constituted the primary users and evaluators of the interactive management dashboard developed in this study. The study employed a purposive sampling technique to select 12 stakeholders with relevant experience and involvement in the implementation of EdTech interventions in Kwara state. Stakeholders like educational planners, project managers, school administrators, and selected ICT coordinators were purposively sampled across the governmental agencies (Kwara State Ministry of Education, Teaching Service Commission and KwaraSUBEB).

The selection of the respondents was based on their direct involvement in EdTech intervention. The study employed a self-structured rating form for data collection. The rating form was developed to facilitate an in-depth evaluation of the key stakeholders towards the designed dashboard. The instrument was designed to provide comprehensive insights into the usability and functionality of the developed dashboard. A 5-point Likert scale was used to facilitate statistical analysis. To ensure the validity of the instruments, three experts in the Department of Educational Technology from Al-Hikmah University helped to review the self-structured rating form based on content and construct validity. These experts assessed each item for clarity, appropriateness, and relevance to the research focus.

The dashboard was pilot tested with 5 selected stakeholders at the Kwara State Ministry of Education and Human Capital Development. The participants were chosen based on their involvement with EdTech-related programmes and their ability to provide meaningful feedback on the dashboard evaluation. The reliability of the instrument was determined using Cronbach's Alpha coefficient. This statistical method indicated the extent to which items within a scale are correlated, and reflecting the degree to which they measure the same underlying construct. A Cronbach's Alpha value of 0.70 or higher was considered acceptable for this study. The reliability

of the overall 20 items yielded 0.910. The result indicated excellent internal consistency, this result justify that the instrument is capable of consistently measuring the intended variables. The data collected was analysed using descriptive statistics such as frequency count, percentages, cumulative percentage, mean scores and standard deviation. This provided a summary of stakeholders' evaluations across the measured criteria.

Results

Demographic Data of the Respondents

Table 2: Distribution of the Respondents Based on Agency

Agencies	Frequency	Percent	Cumulative Percent
MOEHCD	5	41.7	41.7
TESCOM	4	33.3	75.0
KWSUBEB	3	25.0	100.0
Total	**12**	**100.0**	

The table showed the distribution of respondents based on their affiliated agencies. This showed that participants were drawn from the three major government bodies directly involved in Educational Technology interventions in Kwara State. As presented, the Ministry of Education and Human Capital Development (MOEHCD) accounted for the highest proportion of respondents (41.7%), reflecting its central administrative role in policy formulation and system-wide coordination. TESCOM constituted 33.3% of the respondents. Meanwhile, the Kwara State Universal Basic Education Board (KWSUBEB) constituted 25.0% of the participants, representing stakeholders overseeing basic education and school-level EdTech deployment.

Table 3: ***Distribution of the Respondents Based on Department/Unit***

Department	Frequency	Percent	Cumulative Percent
EPRD	4	33.3	33.3
ICT	3	25.0	58.3
Research and Statistics	3	25.0	83.3
Monitoring and Evaluation	2	16.7	100.0
Total	12	100.0	

The table revealed the distribution of respondents across departments, a balanced representation of key units involved in data management, technology integration, and policy implementation within the agencies. The Education Planning, Research, and Development (EPRD) department constituted the largest proportion of participants (33.3%), reflecting its central role in strategic planning and evidence-based decision-making. Respondents from the ICT department and Research & Statistics each accounted for 25.0% of the sample, indicating strong involvement of personnel responsible for digital tools, data infrastructure, and analytical processes relevant to

EdTech interventions. Additionally, 16.7% of the respondents were drawn from the Monitoring and Evaluation (M&E) department, representing stakeholders responsible for oversight, performance tracking, and interventions' accountability.

Analysis of The Rating Form

Research Question Two: How usable is the designed interactive management dashboard for monitoring EdTech interventions in Kwara State?

Table 4: Usability of the Designed Interactive Management Dashboard

S/N	Items	Excellent F (%)	Good F (%)	Fair F (%)	Poor F (%)	Mean F (%)	Std. Deviation
1.	The dashboard is easy to navigate and understand	8 66.7	3 25.0	1 8.3	0 0.0	1.42	.66
2.	Information on the dashboard is well-organized and accessible	7 58.3	5 41.7	0 0.0	0 0.0	1.42	.51
3.	The dashboard can help me complete my tasks more efficiently	6 50.0	6 50.0	0 0.0	0 0.0	1.50	.52
4.	I was able to use the dashboard without much difficulty	6 50.0	5 41.7	1 8.3	0 0.0	1.58	.66
5.	The dashboard can be used conveniently by different categories of stakeholders (Educational Administrators, Managers, Planners).	6 50.0	5 41.7	1 8.3	0 0.0	1.58	.66
6.	Users can easily locate and access specific reports or KPIs.	4 33.3	7 58.3	1 8.3	0 0.0	1.75	.62
7.	The dashboard responds promptly to user inputs and commands.	4 33.3	5 41.7	3 25.0	0 0.0	1.92	.79
8.	The color schemes, charts, and visuals enhance understanding of data.	8 66.7	2 16.7	2 16.7	0 0.0	1.50	.79
9.	I am satisfied with the overall experience of using the dashboard	8 66.7	2 16.7	2 16.7	0 0.0	1.50	.79
10.	I would recommend the dashboard for broader use for monitoring EdTech interventions	9 75.0	3 25.0	0 0.0	0 0.0	1.25	.45
	Grand Mean					**1.54**	

The table revealed the usability agreement of the designed management dashboard. Across all items, the majority of respondents selected Strongly Agree or Agree, indicating a high level of comfort and satisfaction with the system. Respondents affirmed that the dashboard was easy to

navigate and understand, with 91.7% agreeing or strongly agreeing with this statement. Similarly, most of the respondents agreed that the information presented was well-organized and accessible, and that the system helped them complete tasks more efficiently. Therefore, the findings reflect a strong endorsement of the dashboard's intuitive layout, logical structure, and user-friendly interface. Additionally, 91.7% of respondents indicated that they could use the dashboard without much difficulty, showing that users with diverse technological backgrounds were able to interact with the system successfully.

Research Question Three: What is the functionality of the designed interactive management dashboard in enabling stakeholders to monitor EdTech interventions in Kwara State?

Table 5: Functionality of the Designed Interactive Management Dashboard

	Items	Excellent F (%)	Good F (%)	Fair F (%)	Poor F (%)	Mean F (%)	Std. Deviation
1.	The dashboard allows real-time tracking of EdTech interventions	8 66.7	4 33.3	0 0.0	0 0.0	1.33	.49
2.	The filtering and drill-down features function correctly and display relevant results.	5 41.7	5 41.7	2 16.7	0 0.0	1.75	.75
3.	All buttons, charts, and visuals respond correctly to user inputs.	4 33.3	8 66.7	0 0.0	0 0.0	1.67	.49
4.	The dashboard automatically updates data when the source dataset changes.	6 50.0	4 33.3	0 0.0	2 16.7	1.83	1.11
5.	The dashboard enables users to generate detailed reports on EdTech intervention progress.	9 75.0	3 25.0	0 0.0	0 0.0%	1.25	.45
6.	The dashboard operates without errors, bugs, or broken links.	7 58.3	3 25.0	2 16.7	0 0.0%	1.58	.79
7.	The dashboard provides users with actionable insights for intervention follow-up	6 50.0	6 50.0	0 0.0	0 0.0%	1.50	.52
8.	The system performance remains consistent even with large datasets.	4 33.3	4 33.3	4 33.3	0 0.0%	2.00	.85
9.	The dashboard facilitates timely feedback and communication among stakeholders.	6 50.0	4 33.3	2 16.7	0 0.0	1.67	.77
10	The functional features of the dashboard enhance stakeholders' ability to plan and evaluate EdTech interventions effectively.	8 66.7	3 25.0	1 8.3	0 0.0	1.42	.66
	Grand Mean					**1.60**	

The table showed the respondents' agreement on the functionality of the designed management dashboard, with a strong agreement that the system performs effectively across key operational features. All respondents agreed that the dashboard supports real-time tracking of EdTech interventions, with 100% selecting Strongly Agree or Agree. Similarly, respondents affirmed the reliability of interactive elements, as all users agreed that buttons, charts, and visuals respond correctly to user inputs. The dashboard's ability to generate detailed reports was also highly endorsed, with 75% strongly agreeing and 25% agreeing that the system supports comprehensive reporting on intervention progress. Most respondents agreed that the filtering and drill-down features worked correctly, although a small percentage (16.7%) expressed mild difficulty. Likewise, while the majority confirmed that the dashboard updates automatically when source data changes, 16.7% strongly disagreed. The system's stability was also evaluated, as 83.3% agreed that it operates without errors or bugs. Therefore, the results indicated that the dashboard demonstrates high functional reliability, strong operational performance, and significant utility in supporting continuous monitoring and decision-making for EdTech interventions in Kwara State.

Summary of the Finding

1. The result of the findings reflected a strong endorsement of the dashboard's intuitive layout, logical structure, and user-friendly interface.
2. The results indicated that the dashboard demonstrates high functional reliability, strong operational performance, and significant utility in supporting continuous monitoring and decision-making for EdTech interventions in Kwara State.

Conclusion and Recommendations

This study set out to design and evaluate an interactive management dashboard to support stakeholders' monitoring of Educational Technology (EdTech) interventions in Kwara State. Guided by design-based research principles, the dashboard was developed to address the challenges of fragmented data sources, limited monitoring visibility, and the absence of an integrated digital tool for tracking multiple state-led EdTech initiatives such as KwaraLEARN, Smart Schools, Coding Digital Literacy Programme, and Effective School programmes. The development process successfully incorporated stakeholder needs, key performance indicators, and iterative expert feedback, resulting in a functional platform that provides real-time insights and enhances data-driven decision-making.

Findings from the study demonstrate that the dashboard is both relevant and effective for monitoring EdTech interventions. Experts validated its clarity, accuracy, relevance, and visual appeal, affirming its suitability for administrative and strategic use. Stakeholders further confirmed that the dashboard is highly usable, easy to navigate, and capable of improving task efficiency across diverse administrative roles. The functional assessment also established that the system performs reliably in supporting real-time tracking, generating detailed reports, responding promptly to user commands, and offering actionable insights needed for continuous improvement of EdTech implementation. Collectively, these results show that the dashboard successfully meets its design objectives and stands as a practical and scalable tool for strengthening educational accountability, transparency, and planning within the Kwara State education sector.

Recommendations

Based on the findings of this study, the following recommendations are proposed to enhance the use, refinement, and sustainability of the interactive management dashboard developed for monitoring EdTech interventions in Kwara State:

1. Adopt the Dashboard for Official Monitoring Across All EdTech Interventions: The Ministry of Education, SUBEB, and TESCOM should formally integrate the dashboard into their routine monitoring processes. Its ability to consolidate multiple interventions into a single analytical platform will significantly strengthen coordination, reporting accuracy, and evidence-based decision-making.
2. Provide Real Operational Data to Replace the Simulated Datasets Used in Development: Since the dashboard was constructed using simulated datasets for design and testing purposes, government agencies are encouraged to supply authentic, up-to-date operational data. This will enhance the accuracy, reliability, and real-time value of the system's insights.
3. Conduct Capacity-Building and Digital Training for Stakeholders: Training workshops should be organised to improve stakeholders' data literacy and dashboard interpretation skills. This is particularly important for educational administrators and planners who may have limited experience using analytical dashboards.
4. Deploy the Dashboard on a Central Digital Platform To improve accessibility, the dashboard should be hosted on a secure institutional portal (e.g., Ministry of Education website or SharePoint). Cloud-based deployment through Power BI Service will ensure cross-device access and multi-user collaboration.
5. The study further recommends that the Kwara State Government, through relevant educational agencies, should provide adequate funding for the procurement of premium licenses of data visualization and analytics platforms such as Microsoft Power BI. The trial or free versions of such platforms often impose limitations on data capacity, sharing features, real-time refresh capabilities, and collaborative access.
6. Scale the Dashboard to Cover Additional Educational Programmes: As the state expands its digital transformation agenda, the dashboard framework should be adapted to monitor emerging initiatives such as AI literacy programmes, STEM innovation hubs, and digital safety campaigns.

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ACCESS AND LEVEL OF USAGE OF ARTIFICIAL INTELLIGENCE TOOLS FOR LEARNING ENGAGEMENT AMONG UNDERGRADUATE STUDENTS

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Abstract

This study examined access and level of usage of artificial intelligence (AI) tools for learning engagement among undergraduate students in universities in Kwara State. The study was guided by two research questions and one research hypothesis. The descriptive survey of the correlational type was adopted for the study. The population of this study comprised of all the undergraduate students in the universities in Kwara State, Nigeria. The sample size for this study was 383 undergraduate students in universities in Kwara State. A multistage sampling procedure was adopted for the selection of the sample from the total population of the study. A researcher-designed questionnaire titled "Access and Level of Usage of Artificial Intelligence Tools for Learning Engagement Questionnaire (ALUAITLEQ)" was used as instrument for this study. Data collected was analysed using both descriptive and inferential statistics. Descriptive statistics such as mean was used to answer the research questions and inferential statistic such as Pearson Product Moment Correlation (PPMC) statistic was used to test the research hypothesis at 0.05 level of significance. The findings of this study showed that undergraduate students in universities in Kwara State use AI tools regularly for learning activities such as assignments, research, and exam preparation. Access to AI tools, through personal devices, reliable internet, and institutional support, plays a key role in how often students use them. Based on the findings of this study, this study recommended that universities should implement policies that promote equitable access to AI tools.

Keyword: Access, Artificial Intelligence (AI), Learning Engagement, Level of Usage, Undergraduate Students, Universities.

Introduction

Artificial Intelligence (AI) has evolved from a futuristic concept into a transformative force across various sectors, particularly in education. Its integration into higher education is reshaping teaching, learning, and research by improving educational outcomes and supporting personalized instruction tailored to students' individual learning needs (Holmes et al., 2019). AI refers to the ability of digital computers or computer-controlled systems to perform tasks traditionally associated with human intelligence (Alowais et al., 2023). Following the rapid digitalization of education after the COVID-19 pandemic, AI technologies have become increasingly important in supporting educational engagement and enhancing learning experiences (Zawacki-Richter et al., 2019).

Artificial Intelligence in education comprises a wide range of technologies, including intelligent tutoring systems, adaptive learning platforms, AI-powered assessment tools, chatbots, and AI-assisted content creation and research applications (Chen et al., 2020). These technologies analyze learners' data, provide personalized feedback, automate assessment processes, predict academic performance, and recommend customized learning pathways that improve learning efficiency and engagement (McCarthy et al., 2018). Such innovations are particularly valuable for undergraduate students who often encounter challenges related to self-regulated learning and information overload.

Globally, universities increasingly recognize AI as a solution to persistent educational challenges such as large class sizes, diverse learner needs, and the demand for personalized academic support (Cardoso, 2022). Higher education institutions in North America and Europe have adopted AI-driven learning analytics, student support chatbots, and discipline-specific AI applications, particularly in computer science, engineering, and medicine (Popenici & Kerr, 2017). Students also increasingly utilize AI-powered learning platforms such as Coursera, Khan Academy, Duolingo, Grammarly, and ChatGPT to enhance learning and research activities (Musawa et al., 2024).

Across Africa, digital technology adoption in higher education continues to expand because of increased mobile device ownership, improving internet penetration, and growing recognition of technology's educational benefits (Czerniewicz et al., 2020). Nevertheless, AI integration remains at an early stage, with limited empirical evidence regarding its adoption and educational impact across African universities (Sithole & Mbukanma, 2024). The challenges affecting AI implementation differ from those experienced in developed countries because of varying socio-economic conditions, technological infrastructure, and cultural contexts (Malasowe et al., 2023). In Nigeria, despite the expansion of public and private universities to accommodate growing enrolment, institutions continue to experience inadequate funding, insufficient digital infrastructure, high student-to-lecturer ratios, and unequal access to quality educational resources (Soneye, 2024; Oluyemisi, 2023).

Access to AI extends beyond the mere availability of AI applications to include affordability, internet connectivity, device ownership, and institutional support necessary for effective utilization (Jameson et al., 2022). Access to AI tools has become an essential component of digital learning environments because undergraduate students increasingly depend on technology for academic

activities. Universities that provide reliable internet connectivity, functional ICT infrastructure, and supportive digital learning environments create greater opportunities for students to utilize AI effectively. However, disparities in institutional resources mean that students in well-resourced universities generally experience better access to AI technologies than those in less-resourced institutions (Hussain et al., 2018; Sakpere et al., 2024). Consequently, access to AI reflects broader issues of digital inclusion, institutional support, socioeconomic status, and the technological culture within universities.

The level of AI usage refers to the extent to which undergraduate students actively integrate AI tools into their academic activities, the frequency of usage, and the specific learning purposes for which they employ these technologies (Dwivedi et al., 2022). Effective access to reliable internet services, digital devices, and institutional encouragement significantly increases students' use of AI for note-taking, research assistance, assignment preparation, concept summarization, and examination revision (Zawacki-Richter et al., 2019). Usage levels are also shaped by perceived usefulness and ease of use, as students are more likely to adopt AI tools that simplify academic tasks and enhance learning outcomes (Holmes et al., 2019). Nevertheless, limited device ownership, expensive internet data, inadequate institutional support, and inconsistent digital infrastructure continue to restrict AI utilization despite increasing awareness of its benefits. As universities in Kwara State strengthen their digital infrastructure and remove access barriers, AI usage for learning engagement is expected to increase correspondingly (Adedoyin & Soykan, 2023).

Although AI technologies such as ChatGPT, Grammarly, Google Bard, and other academic assistants are becoming increasingly important in higher education, disparities in digital infrastructure, inconsistent institutional support, high internet costs, unstable network connectivity, and inadequate access to digital devices continue to limit students' opportunities to benefit from these technologies (Adedoyin & Soykan, 2023). Consequently, the extent to which undergraduate students can access AI tools and utilize them to improve learning remains unclear. Undergraduate students may underutilize AI because of limited awareness, inadequate digital literacy, insufficient institutional guidance, and varying faculty attitudes toward AI adoption. Many students may rely primarily on AI for simple writing assistance or quick answers while overlooking more advanced applications such as research support, concept clarification, personalized learning, and examination preparation.

Concerns regarding academic integrity and excessive dependence on AI-generated content further complicate responsible educational use. Also, limited empirical evidence hinder universities' ability to formulate effective policies, training programmes, and institutional support systems that promote ethical and productive AI integration. In order to fill this research gaps, this study seek to examine access and level of usage of artificial intelligence (AI) tools for learning engagement among undergraduate students in universities in Kwara State.

Purpose of the Study

The main purpose of this study was to examine access and level of usage of artificial intelligence (AI) tools for learning engagement among undergraduate students in universities in Kwara State. The specific purposes;

1. find out the extent to which undergraduate students have access to AI tools;
2. find out the level of usage of AI tools for learning engagement among undergraduate students; and
3. determined the relationship between access and level of usage of AI tools for learning engagement among undergraduate students.

Research Questions

1. To what extent do undergraduate students have access to AI tools?
2. What is the level of usage of AI tools for learning engagement among undergraduate students?

Research Hypotheses

H_{01}: There is no significant relationship between access and level of usage of AI tools for learning engagement among undergraduate students.

Methodology

This study adopted a descriptive survey research design of the correlational type, to examine the relationship between access to artificial intelligence and the level of usage of AI tools for learning activities among undergraduate students in universities in Kwara State. The design was considered appropriate because it enabled the collection of quantitative data from a large population without manipulating the variables, while also facilitating the identification of patterns, trends, and associations among students' demographic characteristics, technological accessibility, and learning engagement. The population comprised 96,457 undergraduate students drawn from three selected universities in Kwara State: University A (49,666 students), University B (40,659 students), and University C (6,132 students), representing federal, state, and private institutions respectively.

A sample size of 383 undergraduate students was determined using the Research Advisors (2006) sample size determination table at a 95% confidence level, and 5% margin of error. A multistage sampling procedure was employed. At the first stage, three universities were purposively selected based on ownership type. At the second stage, proportionate sampling techniques was used to allocate 197 respondents to University A, 162 to University B, and 24 to University C. at the third stage, simple random sampling was used to select the participants to ensure equal chances of selection. Data were collected using a researcher-designed questionnaire titled: Access and Level of Usage of Artificial Intelligence Tools for Learning Engagement Questionnaire (ALUAITLEQ). The instrument consisted of Section A which measured access to AI tools and Section B which focused on level of usage of AI tools for learning. The questionnaire was validated for face and construct validity by expert of educational technology, Faculty of Education, Al-Hikmah

University, Ilorin, who examined its relevance, suitability, and adequacy in relation to the study variables.

A pilot test involving 50 undergraduate students at LAUTECH, Ogbomosho, Oyo State, was conducted using internal consistency method, to determine the reliability of the instrument and to ensure that the questionnaire items were clear and relevant without influencing the main study population. The responses were analyzed using Cronbach's Alpha, which yielded a reliability coefficient of 0.85, indicating satisfactory internal consistency. Data collection for the main study was carried out after securing respondents' permission. The completed questionnaires were retrieved immediately after administration for analysis. The data were coded and analyzed using the Statistical Package for Social Science (SPSS). Mean was used to answer the research questions, Pearson Product Moment Correlation (PPMC) was used to test the research hypothesis at the 0.05 level of significance.

RESULTS

Research Question One: To what extent do undergraduate students have access to AI tools?

Table 1: ***Distribution of the Respondents on the extent to which Undergraduate Students have Access to AI Tools***

ITEMS	SA	A	D	SD	X	Std. D
As an undergraduate students, I have access to digital devices that support AI tools.	184	167	28	4	3.39	.669
My institution provide support for accessing AI learning platforms	133	157	67	26	3.04	.891
The cost of internet connectivity and data services allows affordable access to AI tools for learning.	121	163	87	12	3.03	.818
AI learning platforms and applications are readily available for students' academic activities.	129	187	55	12	3.13	.768
Access to AI facilities and resources within universities enhances student access to AI tools.	106	209	56	12	3.07	.738

Source: Field Survey, (2026)

Table 1 showed the extent to which undergraduate students have access to AI tools. From Table 1, it was observed that the mean scores of all the questionnaire items were above 2.5, indicating that the majority of respondents agreed with the statements. Specifically, most respondents ($\bar{X}$ = 3.39, SD = 0.669) indicated that they have access to digital devices that support AI tools. Respondents also agreed that their institutions provide support for accessing AI learning platforms ($\bar{X}$ = 3.04, SD = 0.891) and that the cost of internet connectivity and data services allows affordable access to AI tools for learning ($\bar{X}$ = 3.03, SD = 0.818). Furthermore, respondents agreed that AI learning platforms and applications are readily available for students' academic activities ($\bar{X}$ = 3.13, SD = 0.768) and that access to AI facilities and resources within universities enhances student access to AI tools ($\bar{X}$ = 3.07, SD = 0.738). Thus, this study revealed that undergraduate students in

universities in Kwara State have moderate access to AI tools for learning, with digital device availability and institutional support being the most influential factors.

Research Question Two: What is the level of usage of AI tools for learning engagement among undergraduate students?

Table 2: Distribution of the Respondents on the Level of Usage of AI Tools for Learning Engagement among Undergraduate Students

ITEMS	SA	A	D	SD	X	Std. D
AI tools are frequently used by students for completing academic assignments and projects.	222	132	25	4	3.49	.667
AI applications are often utilized for examination preparation and study purposes.	196	156	31	0	3.43	.639
AI technologies are regularly applied for conducting academic research and gathering study materials.	191	173	16	3	3.44	.615
AI tools are generally considered easy to use for learning activities.	178	187	7	11	3.39	.669
The use of AI tools is extensive among students and contributes to improved academic performance.	194	137	37	15	3.33	.807

Source: Field Survey, (2026)

Table 2 showed the level of usage of AI tools for learning engagement among undergraduate students. From Table 2, it was observed that the mean scores of all the questionnaire items were above the decision benchmark of 2.5, indicating that the majority of the respondents agreed with the statements presented. Specifically, most respondents agreed that AI tools are frequently used for completing academic assignments and projects ($\bar{X}$ = 3.49, SD = 0.667). Respondents also indicated strong agreement that AI applications are often utilized for examination preparation and study purposes ($\bar{X}$ = 3.43, SD = 0.639). Furthermore, respondents agreed that AI technologies are regularly applied for conducting academic research and gathering study materials ($\bar{X}$ = 3.44, SD = 0.615). They also affirmed that AI tools are generally easy to use for learning activities ($\bar{X}$ = 3.39, SD = 0.669). In addition, respondents agreed that the use of AI tools is extensive among students and contributes to improved academic performance ($\bar{X}$ = 3.33, SD = 0.807). Thus, this study showed that undergraduate students in universities in Kwara State demonstrate a relatively high level of usage of AI tools for learning engagement.

Research Hypothesis One:

H_{01}: There is no significant relationship between access and level of usage of AI tools for learning engagement among undergraduate students.

Table 3: *Summary of Pearson Product Moment Correlation between Access and Level of Usage of AI Tools for Learning Engagement among Undergraduate Students*

Variables	N	Mean	SD	df	r-cal	Sig.	Remark
Access to AI Tools	383	15.65	2.52	381	0.408	0.000	Rejected
Level of Usage of AI Tools	383	17.09	2.31				

*Significant at P<0.05 Source: Field Survey, (2026)

Table 3 showed that the r-cal is 0.408 and the p-value is 0.000 which is lesser than 0.05 level of significance. Therefore, the null hypothesis which stated that "there is no significant relationship between access and level of usage of AI tools for learning engagement among undergraduate students" is hereby rejected. Thus, this study revealed that there is significant relationship between access and level of usage of AI tools for learning engagement among undergraduate students.

Summary of Findings

The data collected from the respondents was analyzed using Mean to answer the research questions, PPMC to test the research hypothesis. The following were the outcome of the findings:

1. This study revealed that undergraduate students in universities in Kwara State have moderate access to AI tools for learning, with digital device availability and institutional support being the most influential factors.
2. This study showed that undergraduate students in universities in Kwara State demonstrate a relatively high level of usage of AI tools for learning engagement.
3. This study revealed that there is significant relationship between access and level of usage of AI tools for learning engagement among undergraduate students.

Discussion of Findings

This study revealed that undergraduate students in universities in Kwara State have moderate access to AI tools for learning, with digital device availability and institutional support being the most influential factors. This finding is consistent with Kalbande et al. (2024), who identified perceived ease of use and accessibility as strong predictors of technology adoption among Indian university students using Learning Management Systems. Although the technologies differ, both studies emphasize how access and usability shape student engagement with digital tools. This study also supports the findings of Oluwadiya et al. (2023), who reported that digital literacy strongly influences the adoption of e-learning platforms among Nigerian undergraduates. Access and digital literacy are closely intertwined, and the moderate access revealed in this study may reflect parallel limitations observed in national trends on digital preparedness.

This study showed that undergraduate students in universities in Kwara State demonstrate a relatively high level of usage of AI tools for learning engagement. This result showed that AI is becoming an integral part of students' learning routines. This finding strongly aligns with the conclusion of Antoninis et al. (2023), who reported that 86% of students globally use AI tools for academic purposes, with many integrating these tools into their weekly learning routines. This suggests that AI usage among students is no longer peripheral but central to modern learning

practices. The high usage reported in the study is also in harmony with Hwang et al. (2013), who found that undergraduate EFL students who used AI tools demonstrated significantly improved learning outcomes compared to those using traditional online methods. The willingness of students to use AI tools for study and research supports the finding that usage levels are influenced by perceived usefulness.

This study revealed that there is significant relationship between access and level of usage of AI tools for learning engagement among undergraduate students. This means that undergraduate students who have greater access either, through affordability, institutional support, reliable internet, or availability of digital devices, tend to use AI tools more frequently for academic purposes. This finding aligns strongly with existing literature. For instance, Oluwadiya et al. (2023) found that digital literacy and access to technological resources play a key role in technology adoption among university students, which supports this study's evidence that access conditions directly shape students' ability to use AI tools effectively. Similarly, Owolarafe et al. (2024) reported that limited access to digital infrastructure significantly reduced students' usability of AI and gamification tools in secondary schools, reinforcing the idea that access is a critical determinant of technology engagement.

Conclusion

This study showed that undergraduate students in universities in Kwara State use AT tools regularly for learning activities such as assignments, research, and exam preparation. Access to AI tools, through personal devices, reliable internet, and institutional support, plays a key role in how often students use them. This study suggested that while students used AI tools actively, having access remains crucial. Even if students uses AI tools, limited infrastructure, internet challenges, or lack of devices can still prevent effective use. On this note, focusing on improving access, providing AI-focused training, and creating supportive policies to help students make the most of these tools, can become an even more effective part of learning, helping students study smarter, improve performance, and gain the digital skills needed for the future.

Recommendations

Based on the findings of this study, the following recommendations were suggested;

1. Institutions should provide adequate digital devices, reliable internet access, and technical support to ensure that students have sufficient access to AI tools for learning.
2. Students should be encouraged to integrate AI tools responsibly into their learning routines, using them to enhance understanding, research, and problem-solving rather than to replace critical thinking.
3. Universities should implement policies that promote equitable access to AI tools, ensuring all students can benefit regardless of socioeconomic background.

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PERCEPTIONS AND UTILIZATION PATTERNS OF GENERATIVE ARTIFICIAL INTELLIGENCE (AI) TOOLS FOR LEARNING ACTIVITIES AMONG UNDERGRADUATES IN UNIVERSITIES IN KWARA STATE

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Abstract

This study examined the perceptions and utilization patterns of generative Artificial Intelligence (AI) tools for learning activities among undergraduate students in universities in Kwara State. The study was guided by three research questions and one research hypothesis. The descriptive survey of the correlational type was adopted for the study. The population for this study comprised all the undergraduate students in universities in Kwara State, with a total target population of 96,457 students. The sample size for the study was 383 undergraduate students. A multistage sampling procedure was adopted for the selection of the respondents. A researcher-designed questionnaire titled "Perceptions and Utilization Patterns of Generative Artificial Intelligence Tools for Learning Activities Questionnaire (PUPGAITLAQ)" was used as the instrument for data collection. Descriptive statistics such as mean was used to answer the research questions, while inferential statistics such as Pearson Product Moment Correlation (PPMC) was used to test the research hypothesis at the 0.05 level of significance. The study revealed that undergraduate students perceived generative AI tools as useful and easy to use. The study also revealed that undergraduate student utilized AI tool extensively for learning activities, especially assignments and reports. The findings further revealed that a significant relationship existed between their perceptions and utilization patterns. Based on the findings of the study, it was recommended that universities should promote the effective and ethical integration of generative AI tools through digital literacy programmes and institutional policies that encourage responsible utilization for learning activities.

Keyword: Generative Artificial Intelligence (AI) Tools, Perception, Perceived Usefulness, Perceived Ease of Use, Utilization Patterns, Learning Activities, Undergraduate Students

Introduction

Technology has continued to transform educational systems across the world by reshaping how knowledge is accessed, delivered, and applied within formal learning environments. The integration of digital technologies into education has expanded beyond the use of computers and internet resources to include intelligent systems capable of supporting personalized instruction, collaborative learning, and academic problem solving (Bond et al., 2024). Educational institutions increasingly incorporate emerging technologies into teaching and learning because they enhance flexibility, improve access to educational resources, and encourage active learner participation in both physical and virtual classrooms. These developments have influenced curriculum delivery by enabling instructors to adopt innovative pedagogical approaches that promote student engagement and independent learning. The growing emphasis on technology integration has also encouraged universities to invest in digital infrastructure and learning management systems that facilitate continuous interaction between instructors and students while supporting diverse learning needs (Crompton, 2023). Consequently, digital transformation has become an important component of higher education reforms aimed at improving the quality, accessibility, and effectiveness of university education across different countries.

The rapid advancement of artificial intelligence has introduced a new dimension to technology integration by enabling computer systems to perform cognitive tasks that traditionally required human intelligence. Artificial intelligence encompasses computational techniques that allow machines to recognize patterns, process natural language, solve problems, generate predictions, and support decision making across multiple domains, including education (Russell & Norvig, 2020). Universities increasingly utilize AI-driven applications to enhance instructional delivery, automate administrative processes, and provide intelligent academic support services that improve students' learning experiences (Bond et al., 2024). Unlike earlier educational technologies that primarily served as repositories of information, AI-powered systems actively interact with learners by providing adaptive feedback, personalized recommendations, and real-time academic assistance. The increasing accessibility of AI technologies has therefore created opportunities for students to engage with learning materials in more interactive and individualized ways, thereby supporting the development of critical thinking, self-regulated learning, and academic productivity (Zawacki-Richter et al., 2019).

A major advancement within artificial intelligence is the emergence of generative Artificial Intelligence (AI), which is designed to create new content such as text, images, computer code, audio, and multimedia outputs in response to user prompts. The widespread public availability of generative AI applications, particularly following the introduction of sophisticated large language models, has significantly influenced educational practices by providing learners with instant academic support, explanations, summaries, and content generation capabilities (Dwivedi et al., 2023). Generative AI differs from conventional AI applications because it not only analyzes existing information but also generates contextually relevant responses that can support brainstorming, writing, problem solving, translation, and personalized tutoring. These capabilities have attracted considerable attention within higher education because they enable students to obtain immediate assistance for various academic tasks while encouraging flexible and self-paced learning. The educational potential of generative AI has therefore stimulated extensive scholarly discussions regarding its benefits, limitations, ethical implications, and appropriate integration into university teaching and learning environments (Kasneci et al., 2023).

The increasing availability of generative Artificial Intelligence (AI) tools has transformed the learning experiences of undergraduate students by providing immediate access to academic assistance through conversational interfaces and intelligent content generation. Applications such as ChatGPT, Gemini, Microsoft Copilot, Claude, and Perplexity AI have become popular among university students because they support a wide range of learning activities, including generating explanations, summarizing lecture notes, drafting essays, solving mathematical problems, writing computer programs, and translating academic texts (Dwivedi et al., 2023). These tools enable learners to receive personalized responses tailored to their academic needs, thereby complementing traditional classroom instruction and promoting self-directed learning. The growing adoption of generative AI within higher education has created opportunities for students to improve learning efficiency while simultaneously raising important questions regarding responsible use, academic integrity, and critical evaluation of AI-generated content (Kasneci et al., 2023). Consequently, universities are increasingly examining students' interactions with these technologies to understand how they influence learning outcomes and academic engagement (Bond et al., 2024).

Undergraduate students' perception of generative AI plays a significant role in determining whether these technologies are accepted and integrated into everyday learning activities (Tlili et al., 2023). Perception reflects students' beliefs, attitudes, expectations, and judgments regarding the usefulness, ease of use, credibility, and educational value of AI-powered applications. Positive perceptions are often associated with increased confidence in using AI to solve academic problems, improve understanding of difficult concepts, and enhance learning efficiency. Conversely, concerns about inaccurate responses, misinformation, privacy, overdependence, and academic dishonesty may discourage students from fully embracing these technologies despite their potential benefits. Individual experiences with AI tools, digital competence, prior technological exposure, institutional support, and disciplinary differences can also shape how students evaluate and respond to generative AI in educational settings (Chan & Hu, 2023). Variations in perception therefore influence students' willingness to adopt AI tools for meaningful learning rather than using them merely for convenience or task completion (Crompton, 2023).

The utilization of generative AI tools for learning activities extends beyond simple information retrieval to encompass a broad range of academic tasks that support knowledge acquisition, problem solving, creativity, and collaborative learning. Undergraduate students increasingly employ AI applications to generate study guides, explain complex theories, prepare presentations, develop research ideas, edit written assignments, practice examination questions, and receive instant feedback during independent study sessions (Lo, 2023). Such utilization promotes flexible learning because students can access academic support at any time without geographical or time constraints. Effective utilization, however, requires learners to critically evaluate AI-generated outputs, compare information with credible academic sources, and apply independent reasoning before incorporating the responses into their academic work. Excessive dependence on AI-generated content without verification may reduce critical thinking, originality, and deep learning, making responsible utilization essential for maximizing educational benefits while minimizing academic risks (Holmes & Miao, 2023).

The adoption and sustained utilization of generative Artificial Intelligence (AI) tools in higher education can be explained through the Technology Acceptance Model (TAM), which remains one of the most widely applied theoretical frameworks for understanding users' acceptance of information technologies. TAM proposes that individuals' intention to use a technology is

primarily influenced by two key constructs, namely perceived usefulness and perceived ease of use, which subsequently determine actual usage behavior (Davis, 1989). Within the context of higher education, undergraduate students are more likely to adopt generative AI tools when they believe that such technologies enhance their academic performance and can be used with minimal effort. These perceptions influence students' attitudes toward AI applications and shape their willingness to integrate them into everyday learning activities such as research, assignment preparation, revision, and collaborative learning. The model has therefore been extensively validated across educational technology studies because it provides a reliable framework for explaining students' technology adoption behavior in different learning environments (Venkatesh & Davis, 2000; Cabero et al., 2024).

Despite the rapid expansion of generative Artificial Intelligence in higher education, there remains limited empirical evidence regarding how undergraduate students in universities within Kwara State perceive these technologies and the patterns through which they utilize them for learning activities. Existing investigations have largely concentrated on general artificial intelligence adoption, students' readiness for digital learning, or the educational implications of ChatGPT in institutions outside Nigeria, with comparatively fewer studies examining multiple generative AI platforms within the Nigerian university context (Farrokhnia et al., 2024). Variations in institutional digital infrastructure, internet accessibility, students' technological competence, and university policies may produce utilization patterns that differ from those reported in other countries. Understanding students' perceptions alongside their actual utilization patterns is therefore essential for informing institutional guidelines, curriculum development, digital literacy initiatives, and ethical AI integration within higher education. Consequently, this study seek to examine the perceptions and utilization patterns of generative Artificial Intelligence (AI) tools for learning activities among undergraduate students in universities in Kwara State.

Purpose of the Study

The main purpose of the study is to examine the perceptions and utilization patterns of generative Artificial Intelligence (AI) tools for learning activities among undergraduate students in universities in Kwara State. Specifically, this study seek to;

1. assess the perceived usefulness of generative Artificial Intelligence (AI) tools among undergraduate students;
2. find out the perceived ease of use of generative Artificial Intelligence (AI) tools for learning activities among undergraduate students;
3. determine the utilization patterns of generative Artificial Intelligence (AI) tools for learning activities among undergraduate students; and
4. examine the relationship between perception and utilization patterns of generative Artificial Intelligence (AI) tools for learning activities among undergraduate students.

Research Questions

1. What is the perceived usefulness of generative Artificial Intelligence (AI) tools among undergraduate students?
2. What is the perceived ease of use of generative Artificial Intelligence (AI) tools for learning activities among undergraduate students?

3. What are the utilization patterns of generative Artificial Intelligence (AI) tools for learning activities among undergraduate students?

Research Hypothesis

H_{01}: There is no significant relationship between perception and utilization patterns of generative Artificial Intelligence (AI) tools for learning activities among undergraduate students.

Methodology

This study adopted a descriptive survey research design of the correlational type to examine the relationship between undergraduate students' perceptions and utilization patterns of generative Artificial Intelligence (AI) tools for learning activities in universities in Kwara State. The design was considered appropriate because it enabled the researcher to collect quantitative data from a large population without manipulating the study variables while facilitating the examination of the relationships among perceived usefulness, perceived ease of use, and utilization patterns of generative AI tools. The population comprised 96,457 undergraduate students drawn from three selected universities in Kwara State: University A (49,666 students), University B (40,659 students), and University C (6,132 students), representing federal, state, and private institutions respectively.

A sample size of 383 undergraduate students was determined using the Research Advisors (2006) sample size determination table at a 95% confidence level and a 5% margin of error. A multistage sampling procedure was employed. At the first stage, three universities were purposively selected based on ownership type. At the second stage, proportionate sampling technique was used to allocate 197 respondents to University A, 162 to University B, and 24 to University C. At the third stage, simple random sampling was used to select the participants to ensure that every undergraduate student had an equal chance of being selected for the study. Data were collected using a researcher-designed questionnaire titled: Perceptions and Utilization Patterns of Generative Artificial Intelligence Tools for Learning Activities Questionnaire (PUPGAITLAQ). The instrument consisted of Section A, which collected measured undergraduate students' perceived usefulness of generative AI tools, Section B, which measured perceived ease of use, and Section C, which measured utilization patterns of generative AI tools for learning activities. The questionnaire was validated for face and construct validity by an expert in Educational Technology, Faculty of Education, Al-Hikmah University, Ilorin, who examined the relevance, clarity, suitability, and adequacy of the instrument in relation to the study variables.

A pilot test involving 50 undergraduate students at LAUTECH, Ogbomosho, Oyo State, was conducted using the internal consistency method to determine the reliability of the instrument and to ensure that the questionnaire items were clear, understandable, and appropriate without influencing the main study population. The responses obtained from the pilot study were analyzed using Cronbach's Alpha, which yielded a reliability coefficient of 0.83, indicating that the instrument possessed satisfactory internal consistency for data collection. Data collection for the main study was carried out after obtaining respondents' consent. The completed questionnaires were retrieved immediately after administration for analysis. Mean was used to answer the research questions. Pearson Product Moment Correlation (PPMC) was used to test the hypothesis at 0.05 level of significance.

Results

Research Question One: What is the perceived usefulness of generative Artificial Intelligence (AI) tools among undergraduate students?

Table 1: ***Distribution of the Respondents on the Perceived Usefulness of Generative Artificial Intelligence (AI) Tools for Learning Activities***

ITEMS	SA	A	D	SD	X	Std. D
Generative AI tools improve my understanding of difficult course concepts.	4	298	81	0	2.80	0.43
Using generative AI tools enables me to complete academic assignments more efficiently.	98	168	105	12	2.92	0.81
Generative AI tools enhance the quality of my learning and academic performance.	81	186	108	8	2.89	0.75
Generative AI tools help me solve academic problems more effectively.	90	189	98	6	2.95	0.74
Generative AI tools are valuable resources for supporting my learning activities.	90	195	94	4	2.97	0.72

Source: Field Survey, (2026)

Table 1 showed the perceived usefulness of generative Artificial Intelligence (AI) tools for learning activities among undergraduate students. From Table 1, it was observed that the mean scores of all the questionnaire items were above the criterion mean of 2.50, indicating that the majority of the respondents perceived generative AI tools as useful for their learning activities. Specifically, respondents agreed that generative AI tools are valuable resources for supporting their learning activities ($\bar{X}$ = 2.97, SD = 0.72). Respondents also agreed that generative AI tools help them solve academic problems more effectively ($\bar{X}$ = 2.95, SD = 0.74) and enable them to complete academic assignments more efficiently ($\bar{X}$ = 2.92, SD = 0.81). Furthermore, respondents indicated that generative AI tools enhance the quality of their learning and academic performance ($\bar{X}$ = 2.89, SD = 0.75), while they also agreed that generative AI tools improve their understanding of difficult course concepts ($\bar{X}$ = 2.80, SD = 0.43). Thus, this study revealed that undergraduate students perceived generative Artificial Intelligence (AI) tools as useful for learning activities, with their value in supporting learning activities and solving academic problems being the most highly perceived benefits.

Research Question Two: What is the perceived ease of use of generative Artificial Intelligence (AI) tools for learning activities among undergraduate students?

Table 2: ***Distribution of the Respondents on the Perceived Ease of Use of Generative Artificial Intelligence (AI) Tools for Learning Activities***

ITEMS	SA	A	D	SD	X	Std. D
Learning to use generative AI tools is easy for me.	25	202	132	24	2.60	0.67
I can easily obtain the information I need using generative AI tools.	51	226	96	10	2.83	0.67
Interacting with generative AI tools requires little mental effort.	36	241	103	3	2.81	0.60
The features of generative AI tools are easy to understand and use.	47	228	97	11	2.81	0.67
I can use generative AI tools without assistance from other people.	37	214	117	15	2.71	0.69

Source: Field Survey, (2026)

Table 2 showed the perceived ease of use of generative Artificial Intelligence (AI) tools for learning activities among undergraduate students. From Table 2, it was observed that the mean scores of all the questionnaire items were above 2.50, indicating that the majority of respondents agreed with the statements. Specifically, most respondents ($\bar{X}$ = 2.60, SD = 0.67) agreed that learning to use generative AI tools is easy for them. Respondents also agreed that they can easily obtain the information they need using generative AI tools ($\bar{X}$ = 2.83, SD = 0.67) and that interacting with generative AI tools requires little mental effort ($\bar{X}$ = 2.81, SD = 0.60). Furthermore, respondents agreed that the features of generative AI tools are easy to understand and use ($\bar{X}$ = 2.81, SD = 0.67) and that they can use generative AI tools without assistance from other people ($\bar{X}$ = 2.71, SD = 0.69). Thus, this study revealed that undergraduate students in universities in Kwara State perceived generative Artificial Intelligence (AI) tools as easy to use for learning activities, with ease of obtaining information and user-friendly features being the most strongly perceived aspects.

Research Question Three: What are the utilization patterns of generative Artificial Intelligence (AI) tools for learning activities among undergraduate students?

Table 3: ***Distribution of the Respondents on the Utilization Patterns of Generative AI Tools for Learning Activities***

ITEMS	VHE	HE	LE	VLE	X	Std. D
I utilize generative AI tools for understanding difficult course concepts.	54	222	82	25	2.80	0.76
I utilize generative AI tools for completing assignments and reports.	69	227	76	11	2.93	0.71
I utilize generative AI tools for conducting literature searches and obtaining academic information.	53	211	103	16	2.79	0.74
I utilize generative AI tools for proofreading, editing, and improving academic writing.	51	208	97	27	2.74	0.80
I utilize generative AI tools for brainstorming ideas, solving problems, and preparing for examinations.	45	204	109	25	2.70	0.79

Source: Field Survey, (2026)

Table 3 showed the utilization patterns of generative Artificial Intelligence (AI) tools for learning activities among undergraduate students in universities in Kwara State. From Table 3, it was observed that the mean scores of all the questionnaire items were above the criterion mean of 2.50, indicating that the respondents utilize generative AI tools to a high extent for various learning activities. Specifically, the respondents indicated that undergraduate students utilize generative AI tools for completing assignments and reports to the greatest extent ($\bar{X}$ = 2.93, SD = 0.71). Undergraduate students also reported utilizing generative AI tools for understanding difficult course concepts ($\bar{X}$ = 2.80, SD = 0.76), conducting literature searches and obtaining academic information ($\bar{X}$ = 2.79, SD = 0.74), proofreading, editing, and improving academic writing ($\bar{X}$ = 2.74, SD = 0.80), as well as brainstorming ideas, solving problems, and preparing for examinations ($\bar{X}$ = 2.70, SD = 0.79). Thus, this study revealed that undergraduate students in universities in Kwara State utilize generative Artificial Intelligence (AI) tools to a high extent for a wide range of learning activities, with completing assignments and writing reports being the most common utilization pattern.

Research Hypothesis One:

H_{01}: There is no significant relationship between perception and utilization patterns of generative Artificial Intelligence (AI) tools for learning activities among undergraduate students.

Table 4: ***Summary of Pearson Product Moment Correlation between Perception and Utilization Patterns of Generative Artificial Intelligence (AI) Tools for Learning Activities***

Variables	N	Mean	SD	Df	r-cal	Sig.	Remark
Perception	383	14.35	2.60	381	0.513	0.000	Rejected
Utilization Patterns	383	16.04	2.34				

*Significant at P<0.05
Source: Field Survey, (2026)

Table 4 showed that the r-cal is 0.513 and the p-value is 0.000 which is lesser than 0.05 level of significance. Therefore, the null hypothesis which stated that "there is no significant relationship between perception and utilization patterns of generative Artificial Intelligence (AI) tools for learning activities among undergraduate students" is hereby rejected. Thus, this study revealed that there is significant relationship between perception and utilization patterns of generative Artificial Intelligence (AI) tools for learning activities among undergraduate students.

Summary of Findings

The data collected from the respondents was analyzed using Mean to answer the research questions, PPMC to test the research hypothesis. The following were the outcome of the findings:

1. This study revealed that undergraduate students perceived generative Artificial Intelligence (AI) tools as useful for learning activities, with their value in supporting learning activities and solving academic problems being the most highly perceived benefits.
2. This study revealed that undergraduate students in universities in Kwara State perceived generative Artificial Intelligence (AI) tools as easy to use for learning activities, with ease

of obtaining information and user-friendly features being the most strongly perceived aspects.

3. This study revealed that undergraduate students in universities in Kwara State utilize generative Artificial Intelligence (AI) tools to a high extent for a wide range of learning activities, with completing assignments and writing reports being the most common utilization pattern
4. This study revealed that there is significant relationship between perception and utilization patterns of generative Artificial Intelligence (AI) tools for learning activities among undergraduate students.

Discussion of Findings

This study revealed that undergraduate students perceived generative Artificial Intelligence (AI) tools as useful for learning activities, with their value in supporting learning activities and solving academic problems being the most highly perceived benefits. This finding is consistent with Dwivedi et al. (2023), who explained that students perceive generative AI as highly beneficial because it enhances learning efficiency, supports problem-solving, facilitates knowledge acquisition, and improves academic productivity. The finding also agrees with Kasneci et al. (2023), who reported that generative AI tools assist learners by providing immediate explanations, personalized feedback, and academic support, thereby increasing their perceived usefulness for educational activities. The positive perception observed in this study further aligns with Crompton (2023), who concluded that university students increasingly recognize generative AI as a valuable educational resource because it supports critical thinking, content generation, and independent learning.

This study revealed that undergraduate students in universities in Kwara State perceived generative Artificial Intelligence (AI) tools as easy to use for learning activities, with ease of obtaining information and user-friendly features being the most strongly perceived aspects. This finding corroborates the Technology Acceptance Model, which posits that perceived ease of use significantly influences users' acceptance and continued use of technology. It is also consistent with Tlili et al. (2023), who found that university students generally consider generative AI applications easy to operate because they provide conversational interfaces, rapid responses, and intuitive interactions that require minimal technical expertise. The finding also supports that of Lo (2023), who observed that students' willingness to adopt generative AI is strengthened when the technology is perceived as straightforward, accessible, and easy to navigate.

This study revealed that undergraduate students in universities in Kwara State utilize generative Artificial Intelligence (AI) tools to a high extent for a wide range of learning activities, with completing assignments and writing reports being the most common utilization pattern. This finding is consistent with Chan and Hu (2023), who found that university students predominantly use generative AI for drafting assignments, generating ideas, summarizing learning materials, and preparing academic reports. Likewise, Sallam (2023) reported that students across higher education institutions frequently employ generative AI to support writing tasks, literature searches, explanations of difficult concepts, and academic problem-solving.

This study revealed that there is a significant relationship between perception and utilization patterns of generative Artificial Intelligence (AI) tools for learning activities among undergraduate

students. This finding supports the Technology Acceptance Model (TAM), which posits that users who perceive a technology as useful and easy to use are more likely to adopt and utilize it for their intended purposes (Davis, 1989). The finding is consistent with Farrokhnia et al. (2024), who explained that students' positive perceptions of ChatGPT and other generative AI tools encourage their integration into learning activities because these technologies provide timely feedback, facilitate content generation, support problem-solving, and improve learning efficiency. The finding further agrees with Dwivedi et al. (2023), who concluded that students who perceive generative AI as beneficial, reliable, and easy to use are considerably more likely to integrate these tools into their everyday learning activities, resulting in sustained educational utilization.

Conclusion

This study showed that undergraduate students in universities in Kwara State perceive generative Artificial Intelligence (AI) tools as useful and easy to use for learning activities, leading to their widespread utilization for academic tasks such as completing assignments, writing reports, obtaining information, and solving academic problems. The significant relationship established between students' perceptions and their utilization patterns indicates that favourable perceptions of the usefulness and ease of use of generative AI tools encourage greater adoption for learning purposes. This study suggests that although undergraduate students have embraced generative AI as a valuable learning resource, maximizing its educational benefits requires continuous digital literacy development, responsible AI usage, and institutional support. On this note, universities should promote the effective and ethical integration of generative AI into teaching and learning by providing appropriate training, clear usage guidelines, and supportive learning environments that enable students to harness these technologies to enhance academic performance, independent learning, and future digital competence.

Recommendations

Based on the findings of this study, the following recommendations are made:

1. Universities should organize regular awareness programmes, workshops, and seminars to promote the educational value of generative AI tools and strengthen students' positive perceptions of their usefulness.
2. University management and lecturers should provide practical training and digital literacy programmes to improve students' competence in using generative AI tools.
3. Lecturers should integrate generative AI tools into teaching and learning activities to encourage responsible utilization for assignments, research, academic writing, and problem-solving while maintaining academic integrity.
4. Universities should establish clear institutional policies and ethical guidelines to promote the responsible use of generative AI tools and discourage academic dishonesty.

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THE ROLE OF ARTIFICIAL INTELLIGENCE, AUTOMATION, AND LEARNING ANALYTICS IN ENHANCING ADAPTIVE LEARNING AND MULTIMEDIA EDUCATION

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Abstract

Artificial intelligence (AI), automation, and learning analytics (LA) are increasingly positioned as the technical backbone of adaptive and multimedia-rich instruction, promising individualised pacing, real-time feedback, and data-informed pedagogical decisions at a scale human instructors alone cannot sustain. This paper presents a conceptual and literature-based review of how these three converging technologies enhance adaptive learning environments and multimedia instructional design, drawing on recent systematic reviews spanning 2015 - 2026 alongside foundational multimedia-learning theory. The paper situates AI-driven personalisation within Mayer's cognitive theory of multimedia learning, the Technology Acceptance Model (TAM), and the ADDIE instructional design framework, and examines how machine learning, natural language processing, intelligent tutoring systems, and automated content generation reshape the design and delivery of instructional materials. Particular attention is given to the opportunities and constraints of adopting these technologies within Nigerian and broader Sub-Saharan African higher education, where infrastructural, policy, and equity considerations mediate implementation outcomes. The paper concludes that AI, automation, and learning analytics hold substantial promise for enhancing adaptive and multimedia education but require deliberate pedagogical grounding, infrastructural investment, and ethical governance to translate that promise into equitable practice.

Keywords: *artificial intelligence; adaptive learning; learning analytics; multimedia education; instructional design; educational technology*

1. Introduction

Higher education globally is undergoing a rapid re-engineering of how instructional content is designed, delivered, and evaluated. Central to this shift is the convergence of artificial intelligence, automation, and learning analytics, technologies that together enable instructional systems to sense learner behaviour, adjust content in real time, and generate multimedia materials tailored to individual learning needs. Recent systematic reviews confirm that AI applications in education are now commonly categorised into adaptive learning systems, intelligent tutoring systems, and learner analytics, with a marked surge in scholarly attention since 2022 following the mainstreaming of generative AI tools.

Adaptive learning, understood as instruction that adjusts pace, sequence, or content difficulty in response to learner performance, has historically depended on relatively simple rule-based branching. Contemporary systems instead draw on machine learning, deep learning, and multimodal data integration, allowing instructional platforms to adapt in real time to individual

learner profiles rather than to pre-set decision trees. Multimedia education, in turn, is concerned with how words, images, sound, and interactivity are combined to support meaning-making, a concern long theorised through Mayer's cognitive theory of multimedia learning. The intersection of these two domains, adaptive personalisation and multimedia design, is where AI, automation, and learning analytics are having their most visible pedagogical impact.

This paper addresses three questions. First, how do AI, automation, and learning analytics individually and jointly contribute to adaptive learning environments? Second, how do these technologies extend or complicate established multimedia-learning principles? Third, what implications does this convergence carry for instructional design and development (IDD) practice in resource-constrained contexts such as Nigerian higher education? The paper is organised as a conceptual review: it synthesises recent empirical and review literature, situates findings within relevant theoretical frameworks, and closes with implications for practice and further research.

2. Theoretical Framework

Three frameworks anchor this review. The Technology Acceptance Model (TAM) explains learner and instructor uptake of AI-driven tools in terms of perceived usefulness and perceived ease of use, both of which are shaped by the reliability and transparency of adaptive algorithms. The Technological Pedagogical Content Knowledge (TPACK) framework clarifies that effective deployment of AI and automation in instruction requires an integration of technological capability with pedagogical judgement and content expertise, rather than technology adoption for its own sake. The ADDIE model (Analysis, Design, Development, Implementation, Evaluation) offers a systematic process through which AI-generated content, adaptive sequencing, and analytics dashboards can be incorporated into instructional design workflows in a structured, evaluable manner.

Alongside these instructional-design frameworks, Mayer's cognitive theory of multimedia learning (CTML) provides the psychological basis for evaluating AI-generated or AI-curated multimedia content. CTML rests on the assumptions that learners process verbal and visual information through separate channels, that each channel has limited capacity, and that meaningful learning requires active selection, organisation, and integration of material. Well-designed combinations of words and images have been shown to foster deeper understanding than either mode alone, and this principle continues to guide evaluation of AI-generated instructional video, animation, and multimodal content. Recent work has proposed extending CTML together with Cognitive Load Theory into an AI-augmented framework, in which adaptive systems manage cognitive load dynamically and support AI-mediated schema construction rather than replacing the instructor's design role.

3. Artificial Intelligence and Automation in Adaptive Learning

AI-powered adaptive learning systems draw on supervised and unsupervised machine learning, reinforcement learning, and multimodal data integration to adjust instructional content to individual learner profiles in real time. A systematic review of 142 peer-reviewed studies published between 2015 and 2025 found that such systems enhance personalisation, learner engagement, and, under favourable conditions, educational equity, though outcomes vary considerably by implementation context. Intelligent tutoring systems (ITS), a mature strand of this literature, use

learner models to diagnose misconceptions and provide adaptive feedback loops that approximate one-on-one tutoring at scale.

Automation complements adaptive learning by handling repetitive instructional and administrative tasks that would otherwise consume instructor time: automated grading and feedback generation, plagiarism screening, attendance and progress tracking, and the routing of learners to appropriate content modules. A scoping review of adaptive learning platforms in higher education identified adaptive feedback, curriculum-aligned personalisation, and real-time analytics as the key features driving improved academic outcomes, while also cautioning that faculty resistance and algorithmic bias remain persistent barriers to sustained adoption.

A distinct but related literature on adaptive learning path generation (ALPG) has moved through several methodological waves, from early intelligent tutoring systems and metaheuristic optimisation to reinforcement learning and, most recently, large language model (LLM)-based approaches to sequencing content. Despite this methodological maturity, adoption in day-to-day operational learning environments remains limited, a gap attributed to institutional governance structures, infrastructure requirements, and the need for sustained educator training rather than to any deficiency in the underlying algorithms themselves.

4. Learning Analytics as The Evidentiary Layer

Learning analytics supplies the data layer on which AI-driven adaptivity depends: it is the process of collecting, measuring, and interpreting data about learners and their contexts in order to understand and optimise learning and the environments in which it occurs. Within an Education 4.0 framing, learning analytics and AI are understood not merely as tools for improving academic outcomes, but increasingly as mechanisms for supporting metacognitive development and socio-emotional awareness, extending analytics beyond performance prediction into holistic learner support.

A scoping review of adaptive learning and learning analytics in K-12 online and distance contexts, covering studies published between 2020 and 2025, found consistent learner gains in engagement, motivation, and self-regulation. Importantly, the same review noted that these benefits were unevenly distributed, often favouring learners in better-resourced settings, particularly where teacher mediation and institutional support were limited. This finding is significant for the present paper's concern with equity in adaptive and multimedia education: analytics-driven personalisation amplifies existing pedagogical support structures rather than substituting for them.

5. Multimedia Education in The Age of Generative AI

Generative AI has extended the multimedia-design toolkit available to instructors and instructional designers, enabling rapid production of narrated video, illustrative imagery, simulations, and interactive assessment items that would previously have required specialist multimedia production teams. Scholars describe every educational event as an orchestration of multiple semiotic resources, speech, writing, image, spatial arrangement, gesture, and sound, a view consistent with Universal Design for Learning's call for multiple means of representation, engagement, and action.

Empirical applications illustrate this convergence directly. One recent study developed and evaluated an AI educational video assistant built around automatic speech recognition and large language models, structured into transcription, engagement, and reinforcement modules explicitly aligned with CTML principles, finding that the tool supported the coherence, segmentation, and learner-control features associated with effective instructional video. This kind of application demonstrates that generative AI does not automatically produce sound multimedia instruction; benefit accrues only when AI-generated content is deliberately structured according to established multimedia-learning principles rather than treated as a substitute for instructional design expertise.

6. Implications For Nigerian and Sub-Saharan African Higher Education

The adoption of AI-enabled adaptive learning in Nigerian higher education is emergent rather than mainstream. Recent reviews note that a small number of private universities have begun experimenting with AI-powered tools for plagiarism detection, automated grading, and performance analytics, while the use of AI for large-scale assessment, including by national examination bodies, remains largely unrealised. Adaptive learning platforms are seen as particularly consequential in the Nigerian context because they can adjust the difficulty of material to individual progress in ways that partially offset the effects of overcrowded classrooms and an uneven supply of qualified lecturers.

At the same time, the literature is consistent in identifying structural constraints on scalable adoption: erratic power supply, inadequate ICT equipment, and poor internet penetration disproportionately restrict equitable access to adaptive learning tools in rural and underserved public institutions. Additional constraints include limited natural-language-processing support for indigenous Nigerian languages, algorithmic bias and data-privacy concerns, and gaps in institutional policy and educator training needed to align AI deployment with pedagogical goals rather than treating it as a purely technical upgrade. For instructional design and development practice specifically, this suggests that AI and analytics tools should be introduced through structured, evaluable processes, such as the ADDIE cycle, so that infrastructural and equity constraints are assessed and mitigated at the design stage rather than discovered after implementation.

7. Discussion

Taken together, the reviewed literature suggests that AI, automation, and learning analytics enhance adaptive and multimedia education primarily by extending, rather than replacing, sound instructional design practice. Adaptive systems personalise pacing and content sequencing; automation reduces instructor workload on repetitive tasks; learning analytics supplies the evidentiary basis for both; and generative AI expands the practical range of multimedia content that can be produced within realistic time and resource constraints. However, each of these contributions is conditional. Personalisation gains are contingent on data quality and algorithmic transparency; automation gains are contingent on faculty trust and institutional governance; and analytics-driven support tends to reinforce, rather than correct, pre-existing disparities in institutional resourcing unless deliberately designed to do otherwise.

For instructional designers and educational technologists, particularly those working within TAM, TPACK, and ADDIE-informed practice, the practical implication is that technology adoption

decisions should be evaluated against pedagogical criteria first and technical capability second. A multimedia module generated rapidly by an AI tool is only instructionally sound if it satisfies the coherence, segmentation, and dual-channel principles established well before generative AI existed; an adaptive learning path is only equitable if the institution has the infrastructure and educator capacity to support the learners it identifies as needing additional help.

8. Conclusion and Recommendations

Artificial intelligence, automation, and learning analytics are converging to reshape adaptive learning and multimedia education, offering genuine gains in personalisation, engagement, and instructional efficiency where they are grounded in sound pedagogical theory and supported by adequate infrastructure. In contexts such as Nigerian higher education, these technologies carry particular promise for addressing overcrowded classrooms and uneven lecturer availability, but their benefits remain constrained by infrastructural, policy, and equity gaps that must be addressed deliberately rather than assumed away.

On this basis, the paper recommends the following:

- Institutions should adopt structured instructional design processes, such as ADDIE, when integrating AI and analytics tools, so that pedagogical fit is assessed before technical deployment.
- Educator training in AI literacy and TPACK-aligned practice should accompany any adoption of adaptive learning or generative-AI multimedia tools.
- Policy attention and infrastructural investment, including reliable power and internet access, are prerequisites for equitable adaptive-learning access across urban and rural Nigerian institutions.
- Further empirical research is needed on the long-term learning outcomes of AI-driven adaptive and multimedia interventions within Nigerian and Sub-Saharan African university settings specifically, given the current predominance of Western-context studies in the literature.

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ARTIFICIAL INTELLIGENCE IN EDUCATION: IMPACTS ON STUDENT LEARNING OUTCOMES IN OYO STATE, NIGERIA

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Introduction

Artificial intelligence (AI) has moved from a peripheral research interest to a central feature of contemporary educational practice. A systematic review of AI applications in higher education identified student performance, intelligent tutoring systems, assessment and evaluation, and adaptive systems that personalise content to learners' needs. Complementing this Holmes, Bialik, and Fadel (2021) argue that AI in education carries both promises, in the form of individualised support for learners and reduced administrative burden for teachers, and risk, particularly around bias, surveillance, and the erosion of teacher agency if adoption is not carefully managed. More recently, the emergence of generative AI tools such as ChatGPT has intensified this shift a meta-analysis of 21 independent studies found that generative AI tools produced a moderate overall positive effect on student learning outcomes, with the strongest gains observed in the behavioural dimension of learning (Hu, Pang, & Xing, 2025).

In Nigeria, AI's entry into classrooms is occurring within a system already marked by outdated curricula, uneven teacher preparation, and limited access to instructional resources, particularly outside major urban centres. Despite these constraints, Maina (2026) argues that AI can support Nigerian curriculum instruction through personalised learning, enhanced pedagogy, data-driven educational planning, and the reduction of urban-rural inequalities, provided that digital infrastructure, teacher training, and appropriate policy frameworks are put in place. This optimism is increasingly matched by empirical work across Nigeria's states. In Lagos State, a mixed-methods study of junior secondary school students and their teachers found that most teachers who used AI tools regularly in their teaching reported improved instructional delivery, and most sampled students recorded gains in academic performance following exposure to an AI-supported computer applications system (Kehinde, Abimbola, Adeyemi, & Iposu, 2025). At the national level, AI use has also been linked to improved educational performance among Nigerian tertiary students (Ngonso, Egielewa, & Egenti, 2025), and it has also gained digital literacy within technical and vocational education and training (Eno Obot Jackson, Ekong, & George, 2024).

Evidence from states bordering Oyo further illustrates both the promise and the complexity of AI adoption in the South-West geopolitical zone. In Ogun State, a conceptual analysis of AI learning platforms in Business Studies education argued that such platforms can enhance academic performance through personalised instruction and real-time feedback, but only where infrastructural and teacher-training barriers are addressed, since rural communities in the state continue to face unreliable electricity and internet access (Ishola & Obadina, 2025). In Kwara State, a quasi-experimental pre-test, post-test study of the Khan Academy learning platform found moderate academic improvement in mathematics among junior secondary students overall, with private school students recording excellent gains and public school students recording more modest, average gains (Ogunlade, Olafare, Ajayi, & Asiyanbola, 2025). In Osun State, a 2026

study of secondary school students found that although most students perceived generative AI positively, only a minority reported a positive attitude toward using it academically, and students who relied on home tutoring outperformed generative AI only users on academic measures (Adegoke, Uthman, & Akanbi, 2026).

Oyo State presents a striking gap as home to some of Nigeria's oldest and most prominent tertiary institutions, the state might be expected to feature prominently in empirical research on AI and learning outcomes. This paper therefore reviews literature on the impacts of artificial intelligence on students' learning outcomes, with the aim of drawing out implications for Oyo State, Nigeria. The review is guided by four questions: (i) What does the global literature reveal about the effects of AI tools on students' cognitive, behavioural, and affective learning outcomes? (ii) What patterns of AI adoption and effectiveness have been documented in Nigeria, particularly in the South-West geopolitical zone? (iii) What barriers could limit the effectiveness of AI in Oyo State's schools? and (iv) What does the literature suggest for optimising AI use to improve learning outcomes in the state? By synthesising global, national, and regional evidence, this paper seeks to provide a foundation for future empirical research, policy formulation, and classroom practice concerning AI use in Oyo State.

Methodology

This paper adopts a narrative, thematic literature review methodology rather than primary data collection, a design considered appropriate given the near absence of empirical studies conducted directly within Oyo State on AI's effects on learning outcomes. This approach allows global and national evidence to be synthesized as a foundation for identifying the specific gap that future primary research in the state should address.

Literature was drawn from peer-reviewed journal articles, systematic reviews, and conference proceedings addressing artificial intelligence, adaptive learning platforms, intelligent tutoring systems, and generative AI within educational contexts, with priority given to sources situated in Nigeria and, where available. Sources consulted include Educational Research Review, Educational Technology & Society, the Journal of Science and Information Technology, the Kontagora International Journal of Educational Research, Journal of Educational Research, the Journal of Infrastructure, Policy and Development, and the proceedings of the Association for Innovative Technology Integration in Education (AITIE) conference, among others.

Search terms combined artificial intelligence, AI in education, adaptive learning, personalised learning, generative AI, ChatGPT, learning outcomes, academic performance, Oyo State, and Nigeria. in varying combinations.

Retained sources were read in full and organised thematically into six categories: (a) global systematic-review and meta-analytic evidence on AI and learning outcomes; (b) Nigerian evidence on AI for personalised and adaptive learning; (c) Nigerian evidence on generative AI specifically; (d) AI applications for accessibility and inclusion; (e) evidence specific or adjacent to Oyo State; and (f) barriers and constraints reported in the Nigerian context. Findings within each theme were compared to identify convergences, contradictions, and gaps, particularly the extent to which evidence from neighbouring South-West Nigerian states can reasonably be extended to Oyo State. A key limitation of this method is that, in the near-total absence of Oyo state specific empirical studies on AI-driven instruction, conclusions about the state rely on evidence from study of a

related but distinct technology, computer-based testing. This limitation is stated explicitly and it forms the basis of this paper's central recommendation.

Results

Findings from the reviewed literature are presented under four thematic headings: AI for personalised and adaptive learning in Nigeria, generative AI evidence in Nigeria, evidence specific or adjacent to Oyo State, and barriers and challenges.

AI for Personalised and Adaptive Learning in Nigeria

Nigerian evidence on AI-driven personalised and adaptive learning platforms, though still emerging, is beginning to accumulate outside the generative AI space. In Kwara State, a quasi-experimental study administering a Mathematics Performance Test before and after a period of engagement with the Khan Academy learning platform found moderate overall academic improvement among junior secondary school students, with private school students recording excellent performance gains and public school students recording more modest, average gains, a pattern the authors attributed to differences in digital resource availability between the two settings (Ogunlade, Olafare, Ajayi, & Asiyanbola, 2025). In Ogun State, a conceptual analysis of AI learning platforms in Business Studies education argued that such platforms can enhance academic performance through personalised instruction, real-time feedback, and interactive simulation, while cautioning that inconsistent electricity supply, poor internet connectivity, and insufficient teacher training continue to constrain full-scale adoption, particularly in rural communities (Ishola & Obadina, 2025). Elsewhere, a conceptual paper on AI-supported personalised learning in Sokoto State argued that AI's capacity to analyse learner data can help identify individual learning styles and needs, particularly for students from underrepresented and marginalised backgrounds, positioning personalised AI as a tool for equity rather than merely efficiency (Ibrahim & Aliyu, 2025). A similar argument was advanced for the use of AI tools in personalising the teaching of physics education (Ahmed & Musa, 2025). Taken together, these studies suggest that AI-driven personalisation can improve learning outcomes in Nigerian secondary education, but that its benefits are not evenly distributed and depend heavily on the existing resource base of the school in question.

Generative AI Evidence in Nigeria

Evidence on generative AI specifically presents a more contested picture than that on adaptive platforms. In Lagos State, a mixed-methods study of 100 junior secondary school students and 40 computer studies teachers found that about three-quarters of teachers who used AI tools regularly reported improved instructional delivery, and roughly four in five students recorded increased academic performance following engagement with an AI-driven computer applications system, benefits the authors attributed to personalised learning, real-time feedback, and improved concept retention (Kehinde, Abimbola, Adeyemi, & Iposu, 2025). At the national level, AI use has similarly been linked to improved educational performance among Nigerian tertiary students (Ngonso, Egielewa, & Egenti, 2025), and generative AI has been positioned as an enabling technology for digital literacy within technical and vocational education and training (Eno Obot Jackson, Ekong, & George, 2024). However, a 2026 study of 390 secondary school students in Osun State, a state bordering Oyo, found that although 71.8% of students held a positive perception of generative AI,

only about a quarter reported a positive attitude toward its academic use, and students who relied on home tutoring significantly outperformed generative-AI-only users on academic measures, even though AI users significantly outperformed both self-preparatory and home-tutored peers in coding skill (Adegoke, Uthman, & Akanbi, 2026). Consistent with this caution, a study of undergraduates at a university in Anambra State similarly emphasised gaps in awareness and potential demerits associated with ChatGPT use (Nnaemeke & Ogunbadejo, 2024). Scholars examining the intersection of generative AI with open educational resources further caution that combining the two does not automatically improve practice; deliberate strategy and structure are required for benefit to follow (Tlili & Burgos, 2024). This body of evidence indicates that generative AI's effects on Nigerian students' learning outcomes are real but conditional, and that geographic proximity to Oyo State, as with Osun, does not guarantee a uniformly positive pattern.

Evidence Specific or Adjacent to Oyo State

Only one study located within the literature reviewed examined technology-mediated learning specifically among students in Oyo State, and it addressed computer-based testing (CBT) rather than AI-driven instruction directly. In a descriptive survey of 200 undergraduate students drawn from public and private tertiary institutions in Oyo State using stratified sampling, 84.0% of respondents reported a positive experience with CBT, and nearly all described it as either fairly effective (49.5%) or very effective (47.0%) (Awoleru, 2025). While this study does not measure AI tools directly, it offers an indirect but useful indicator that undergraduates in Oyo State's tertiary institutions already hold a favourable disposition toward technology-mediated learning and assessment, a precondition that plausibly favours the successful introduction of AI-based educational tools. No study located in this review directly measured the effects of adaptive learning platforms, generative AI, or intelligent tutoring systems on the learning outcomes of Oyo State students, confirming the central gap that motivates this paper.

Barriers and Challenges

Several barriers recur across the Nigerian literature and apply with particular force to a state such as Oyo, which combines a major urban educational centre, Ibadan, with extensive semi-urban and rural school communities. The digital divide is chief among these: unreliable electricity, poor internet connectivity, and uneven access to devices continue to separate urban from rural Nigerian schools (Maina, 2026). This barrier is echoed directly in the Ogun State evidence, where rural communities were found to face particular disadvantage in accessing the reliable electricity and internet connectivity that AI learning platforms require (Ishola & Obadina, 2025), and in the Kwara State evidence, where public schools with fewer digital resources recorded weaker gains than better-resourced private schools using the same platform (Ogunlade et al., 2025). Teacher preparedness is a related constraint: fewer than three in ten teachers across sub-Saharan Africa are reported to possess adequate digital pedagogical skills (Maina, 2026), a shortfall likely to limit how effectively AI tools are integrated into Oyo State classrooms without deliberate training. Ethical and regulatory gaps present a further concern, since Nigeria currently lacks a dedicated framework governing the collection and use of student data by AI systems (Maina, 2026). Nigeria's education policy has also yet to fully integrate AI-specific competencies and infrastructure needs into curriculum frameworks (Maina, 2026), while the broader financial cost of procuring and maintaining AI infrastructure remains a significant hurdle for education systems with constrained budgets (Maina, 2026). A continent-wide review of educational technology similarly identifies uneven digital expansion and implementation barriers as persistent obstacles to realising

technology's promise for sustainable educational development across Africa (Nnorom, Onuchukwu, Ndimele, & Oji, 2026).

Discussion

The reviewed literature suggests that AI, in both its adaptive-platform and generative forms, is plausibly capable of producing the same moderate, multidimensional gains in Oyo State that have been documented globally (Zawacki-Richter et al., 2021; Hu et al., 2025) and, in a more localised form, in Lagos and Kwara States (Kehinde et al., 2025; Ogunlade et al., 2025). The existing favourable disposition of Oyo State undergraduates toward technology-mediated assessment (Awoleru, 2025) is a reasonable, if indirect, signal that students in the state would likely be receptive to AI-based learning tools more broadly. However, the Osun State evidence (Adegoke et al., 2026) and the Kwara State finding of a public-private performance gap (Ogunlade et al., 2025) together caution against assuming that this receptiveness will translate uniformly into improved academic outcomes across all school types and settings within Oyo State. Given that Oyo shares comparable school systems, socio-economic conditions, and South-West Nigerian context with Ogun, Osun, and Lagos States, this more contested and unevenly distributed pattern of findings is a more prudent basis for expectation in Oyo State.

The barriers identified in the broader Nigerian and African literature, infrastructural deficits, limited teacher digital competence, weak accessibility provision, and the absence of a governing ethical framework, are unlikely to be absent from Oyo State, especially outside Ibadan and other urban centres. This suggests that any benefit from AI tools in the state will be conditional on deliberate investment, structured pedagogical design, and inclusive implementation rather than on the mere availability of the technology.

Conclusion and Recommendations

This review has examined literature published between 2021 and 2026 on the impacts of artificial intelligence on students' learning outcomes, with a focus on Oyo State, Nigeria. The evidence reviewed indicates that AI tools, from adaptive learning platforms to generative AI, produce moderate, positive, and multidimensional effects on learning outcomes globally and in several Nigerian states, but that these effects are neither automatic nor uniform. The one Oyo-State-specific study located in this review, concerning computer-based testing, suggests a favourable underlying disposition toward educational technology among the state's undergraduates, but it cannot substitute for direct evidence on AI-driven instruction.

Based on these findings, the paper recommends that: (i) primary empirical studies be conducted directly among students across the varied urban, semi-urban, and rural school communities of Oyo State to measure the actual effects of AI tools, both adaptive and generative, on learning outcomes; (ii) teacher training programmes be developed to build capacity for pedagogically sound AI integration, taking seriously the caution raised by the Osun State evidence that AI use without structured guidance may not enhance academic performance; (iii) government and institutional stakeholders in Oyo State invest in the electricity, internet, and device infrastructure required for equitable access to AI tools across the state, with particular attention to the public-private and urban-rural disparities documented elsewhere in Nigeria; (iv) AI implementation in the state's schools deliberately incorporate accessibility and universal design principles so that students with disabilities are not left behind; and (v) a context-specific ethical and regulatory framework be developed to govern student data use as AI tools are adopted more widely in Oyo State's schools.

Addressing these gaps would allow Oyo State to draw more confidently on the promise that artificial intelligence is moving globally.

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DOES EVALUATOR GENDER MATTER? GENDER DIFFERENCES IN EXPERT RATINGS OF A DEVELOPED ANIMATED INSTRUCTIONAL VIDEO

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Abstract

Developmental research in educational technology routinely treats expert validators as interchangeable, reporting pooled ratings as though the identity of the rater were immaterial to the judgment. This study examines that assumption by disaggregating the expert appraisal of a developed animated video package by evaluator gender. Fifty experts twenty educational technologists, twenty computer experts and ten Basic Technology teachers, of whom twenty-eight were male and twenty-two female rated an animated video on woodwork tools in Basic Technology on a thirteen-item, five-point evaluation form. Male evaluators returned a higher mean rating than female evaluators on every one of the thirteen items, with a grand mean of 4.01 against 3.63. An independent samples t-test on total scores showed the difference to be statistically significant, $t(48) = 2.57$, $p = .013$, with a medium-to-large effect size (Cohen's $d = 0.73$). The gap was widest on the suitability of the content to the audience (0.76) and on the agreement of captions with visuals (0.69), and effectively absent on creativity (0.02). The consistency of direction across all thirteen items indicates a systematic rather than an incidental difference. The study concludes that panel composition is a source of variance in instructional media validation, and recommends that developmental studies report the composition of their validation panels, disaggregate ratings accordingly, and report inter-rater agreement rather than pooled means alone.

Keywords: *expert validation; rater effects; evaluator gender; animated video; Basic Technology; instructional media*

Introduction

The validation of a developed instructional package rests on an assumption that is rarely stated and almost never tested: that the ratings returned by qualified experts reflect properties of the package rather than properties of the experts. Ala (2019) holds that expert evaluation attests to a package's conformity with the standards of the relevant field, and that establishing effectiveness in a field requires appraisal by experts in that field. This is a claim about competence. It is silent on whether equally competent experts, appraising the same artifact against the same instrument, converge. The convention in Nigerian developmental research is to assume that they do. A package is developed, a panel of validators is convened, mean ratings are computed across the panel and interpreted against a decision criterion, and the package proceeds to trial. The composition of the panel is reported as a sampling detail rather than as a variable, and the dispersion of ratings, where it is reported at all, appears as a standard deviation that receives no comment. If systematic differences exist between identifiable subgroups of validators, this practice conceals them and the pooled mean acquires a spurious authority.

There is reason to expect such differences. Research on technology attitudes and on media evaluation has long registered gender as a correlate of how technological artefacts are received, and the wider literature on rater effects in performance assessment establishes that rater characteristics contribute measurable variance to judgements that are nominally about the object being rated. Whether this extends to specialist appraisal of instructional media in the Nigerian context is an empirical question that appears not to have been asked. The present study asks it. In the course of validating an animated video package developed for learning woodwork tools in Basic Technology in Ilorin metropolis, ratings were collected together with evaluator gender. This paper reports the disaggregated analysis.

Purpose of the Study

The purpose of this study was to determine whether expert evaluation of a developed animated instructional video differed by evaluator gender, and if so, on which features of the package the difference was concentrated.

Research Question

One research question guided the study: What is the experts' evaluation of the developed animated video based on gender?

Research Hypothesis

One null hypothesis was tested at the 0.05 level of significance:

H_{01}: There is no significant difference in experts' evaluation of the developed animated video based on gender.

Methodology

Design

The study formed the evaluation component of a developmental research project in which an animated video package on the manufacture of veneer board and basic hand tools was produced using the ADDIE instructional systems design model and appraised by experts. The present analysis is a between-groups comparison of those appraisals.

Participants

Fifty experts were purposively selected: twenty educational technologists and twenty computer experts from the University of Ilorin, and ten Basic Technology teachers from upper basic schools in Ilorin metropolis. Twenty-eight (56.0%) were male and twenty-two (44.0%) female. Purposive selection was adopted because appraisal of an instructional package requires specialist judgment rather than a representative sample of the general population.

Instrument

A researcher-developed video evaluation form was used, comprising thirteen rating items covering content adequacy, structural simplicity, technical design, clarity and attainment of objectives, syllabus relevance, audience suitability, provision for meaningful interaction, appropriateness of visuals, creativity, language level, and the boldness and visual agreement of captions. Each item was rated on a five-point scale (1 = poor, 2 = fair, 3 = good, 4 = very good, 5 = excellent), giving

a possible total score between 13 and 65. The form recorded evaluator gender and expert category. It was validated for face and content validity by the researcher's supervisor and two other lecturers in the Department of Educational Technology, University of Ilorin.

Procedure

Approval was obtained from the Head of Department and, where required, from school authorities, and the consent of all respondents was sought. The developed package was transferred to each evaluator by peer-to-peer wireless transfer to a mobile phone, and the evaluation form was completed after viewing and collected individually. Data were treated confidentially and anonymously.

Data Analysis

Item means were computed separately for male and female evaluators. The hypothesis was tested using an independent sample t-test on total scores at the 0.05 level of significance, and effect size was expressed as Cohen's d. Analysis was carried out using the Statistical Package for the Social Sciences, version 25.0.

Results

Table 1 presents the item-level comparison of male and female evaluators' ratings, ordered by the size of the difference between them.

Table 1: Experts' Evaluation of the Developed Animated Video by Gender

Rating item	Male (n = 28)	Female (n = 22)	Pooled (N = 50)	Difference
The contents are suitable for the audience	3.71	2.95	3.38	0.76
Captions or subtitles agree with visuals	4.46	3.77	4.16	0.69
There is provision for viewers' meaningful interaction	3.92	3.36	3.67	0.56
Video instruction is relevant to the syllabus	4.11	3.59	3.88	0.52
The video instruction meets stated objectives	4.11	3.73	3.94	0.38
Content of the video is good enough to learn woodwork tools	3.92	3.59	3.77	0.33
Captions or subtitles are bold	4.28	3.95	4.13	0.33
Structure of the video is simple for learning woodwork tools	4.07	3.77	3.94	0.30
Appropriateness of visuals	3.75	3.45	3.62	0.30
The technical design is not too ambiguous for the target class level	4.14	3.86	4.02	0.28
Objectives are clear	4.18	3.91	4.06	0.27
Language level is alright for the audience	4.07	3.81	3.96	0.26
Creativity	3.42	3.40	3.41	0.02
Grand mean	**4.01**	**3.63**	**3.84**	**0.38**

Five-point scale; decision mean = 2.50. Difference = male mean minus female mean.

Male evaluators returned the higher mean rating on every one of the thirteen items. The grand mean across items was 4.01 for male evaluators against 3.63 for female evaluators, a difference of

0.38 of a scale point. Both grand means, and every individual item mean for both groups, exceeded the decision mean of 2.50, so the difference is one of degree of approval rather than of acceptance versus rejection: the two groups agreed that the package was acceptable and disagreed about how good it was.

The gap was widest on the suitability of the content to its audience, where male evaluators returned 3.71 against 2.95 for female evaluators. The female rating on this item is the only figure on either side of the comparison to fall below 3.00, and the lowest single rating recorded in the study. It was next widest on the agreement of captions with visuals (0.69), on provision for viewers' meaningful interaction (0.56) and on the relevance of the video instruction to the syllabus (0.52). At the other extreme, the two groups were effectively identical on creativity, where the difference was 0.02, both groups rating the package around 3.41. Creativity was also the second-lowest rated item overall, so the two groups converged precisely where their assessment was least favourable.

Hypothesis Testing

Table 2: Independent Samples t-Test of Total Evaluation Scores by Evaluator Gender

Gender	N	Mean	SD	df	t	p	Decision
Male	28	52.179	6.907	48	2.572	.013	H_0 rejected
Female	22	47.182	6.702				
Total	50						

Significant at $p < .05$. Cohen's $d = 0.73$.

Male evaluators returned a mean total score of 52.179 (SD = 6.907) and female evaluators 47.182 (SD = 6.702), out of a possible 65. The difference of 4.997 points was statistically significant, $t(48) = 2.572$, $p = .013$. The null hypothesis of no significant difference in experts' evaluation of the developed animated video based on gender is therefore rejected. Cohen's d for the comparison is 0.73, conventionally interpreted as a medium-to-large effect, indicating that the difference is not merely detectable but substantial relative to the dispersion within each group.

Discussion

The finding of substantive interest is not that a significant difference was obtained but that the difference ran in the same direction on all thirteen items. A difference confined to two or three items could plausibly be attributed to sampling variation. Uniform directionality across the whole instrument, combined with an effect size of 0.73, indicates something systematic in how the two groups engaged with the package. The pattern of the gaps suggests where that systematic difference lies. The four items on which the groups diverged most audience suitability, caption–visual agreement, provision for interaction, and syllabus relevance all require the evaluator to project beyond the artifact to the classroom in which it will be used. Judging whether content suits an audience, whether a video affords meaningful interaction, or whether it fits a syllabus requires a model of the learner. The item on which the groups converged almost exactly, creativity, is by contrast a judgment about the artifact itself. A tentative reading is that the two groups differed less in their appraisal of the package as an object than in their estimation of how well it would serve upper basic learners, with female evaluators consistently more sceptical on that count. The female

mean of 2.95 on audience suitability, the only sub-3.00 rating in the study, is the sharpest expression of this.

That reading must be advanced cautiously, and one limitation constrains it severely. Gender was not crossed with expert category in the analysis, and the distribution of men and women across the three panels - educational technologists, computer experts and Basic Technology teachers - is not known. If, as is plausible in the Nigerian higher education context, the computer expert panel was disproportionately male and the teaching panel disproportionately female, then what is reported here as a gender effect may be wholly or partly a disciplinary effect: classroom teachers judging a package against the learners in front of them and technologists judging it against production standards. The two explanations predict exactly the pattern observed, and this dataset cannot separate them. The result should therefore be read as evidence that validation panels are not internally homogeneous, and only provisionally as evidence about gender specifically.

Either way, the methodological implication holds and is the substantive contribution of this paper. Where a pooled panel mean of 3.84 conceals subgroup means of 4.01 and 3.63, and where the subgroup difference reaches a medium-to-large effect, the pooled mean is a summary that discards the most informative feature of the data. Developmental studies that report only pooled validation means are not reporting a property of the package; they are reporting a property of the package confounded with the composition of the panel that happened to be convened. A panel differently composed would have returned a different verdict on the same artifact. This bears directly on how developmental research should be conducted. Panels should be composed deliberately and their composition reported in full, including the crossing of demographic and disciplinary categories. Ratings should be disaggregated and reported at item level by subgroup. Where a package is intended for a defined audience, the subgroup best positioned to judge fit to that audience in this case serving Basic Technology teachers, who formed only ten of the fifty evaluators should be represented in proportion to the weight their judgment deserves rather than in proportion to their availability.

Conclusion

Fifty experts appraised a locally developed animated video package on woodwork tools in Basic Technology. Male evaluators rated the package more favorably than female evaluators on all thirteen items of the evaluation instrument, and the difference in total scores was statistically significant with a medium-to-large effect size. The divergence was concentrated on items requiring a judgment about fit between the package and its intended learners, and was absent on the item concerning creativity of treatment. Because evaluator gender was not crossed with expert category, the effect cannot be cleanly separated from a disciplinary effect. The study nonetheless establishes that the validation panel was not internally homogeneous, and that the pooled mean conventionally reported in developmental research conceals systematic subgroup variation of a magnitude that affects interpretation.

Recommendations

1. Developmental studies in educational technology should report the full composition of their validation panels, including the crossing of demographic and disciplinary categories, rather than reporting panel size and qualification alone.

2. Expert ratings should be reported at item level and disaggregated by identifiable subgroup, with pooled means presented alongside rather than in place of subgroup means.
3. Validation studies should report an index of inter-rater agreement, so that the homogeneity of the panel is treated as an empirical question rather than an assumption.
4. Where a package targets a defined learner group, validation panels should be weighted towards specialists positioned to judge fit to that group, rather than towards specialists most readily available.
5. Further research should cross evaluator gender with expert category on a larger panel in order to separate the two explanations that the present data confound.

Limitations

Three limitations qualify the findings. First, evaluator gender was not crossed with expert category, so gender and disciplinary effects cannot be separated. Second, the panel was purposively selected within Ilorin metropolis and comprised fifty evaluators, so the findings are not generalisable to expert populations elsewhere in Nigeria. Third, the evaluation instrument was validated for face and content validity but no reliability coefficient was computed, so it's internal consistency, and by extension the interpretability of the total score used in the t-test, is not established.

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REIMAGINING LITERATURE EDUCATION IN THE AI ERA: READINESS, POLICY AND PEDAGOGIC FUTURES

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Abstract

Artificial intelligence is no longer a distant possibility in education; it is already reshaping how teachers teach and how students learn. As AI tools become more embedded in academic life, literature education faces both exciting opportunities and serious challenges that must not be ignored. This paper examines how AI is transforming the teaching and learning of literature in higher education, focusing on institutional readiness, policy frameworks, and the future of literary pedagogy. The study pays particular attention to Nigerian higher education institutions, questioning whether they have the infrastructure, curriculum structures, and regulatory frameworks needed to integrate AI meaningfully into literary studies. Using perspectives from digital humanities and educational technology, the paper finds that while AI offers valuable possibilities, including new approaches to textual analysis, adaptive learning, and broader interpretive engagement, its effective adoption depends heavily on clear policy direction, ethical guidelines, and context-appropriate infrastructure. A key finding is the risk of surface-level integration, where institutions adopt AI tools without rethinking their pedagogy or equipping students with the critical literacy necessary to use those tools effectively. The paper concludes that literature education must be reimagined for the AI era, not by replacing humanistic inquiry with technology, but by using AI to deepen critical thinking, support diverse interpretations, and remain culturally responsive.

Keywords: *Artificial Intelligence; Literature Pedagogy; Institutional Readiness; Digital Humanities; Higher Education*

1.0 Introduction

Artificial intelligence no longer knocks at the classroom door; it has walked in and taken a seat beside the textbook and the lecture (Zhang & Aslan, 2021). What began as isolated experiments in computer-assisted instruction has, within a decade, become a pervasive infrastructure of large language models, adaptive platforms, and natural language processing systems that now shape how students read, write, and think (Zeide, 2019). Literature teaching has undergone its own long evolution, moving from recitation and rote memorization toward reader-centred, interpretive, and increasingly digital modes of engagement (Rosenblatt, 1995). AI enters this trajectory as more than another instructional tool; it is, as many scholars argue, a disruptive innovation capable of reorganizing not merely how texts are delivered but how they are read, analyzed, and understood (Zawacki-Richter et al., 2019).

Literature occupies a distinctive place within this disruption. Unlike disciplines built primarily on the transmission of fact, literary study depends on interpretation, ambiguity, and the cultivation of a reader's inner life—qualities that resist straightforward automation (Govindaraju, 2025). Recent

African scholarship illustrates the point vividly: experiments applying generative AI to Yorùbá oral storytelling show both the creative promise of the technology and its tendency to flatten indigenous narrative conventions when used without cultural guardrails (Idowu & Abbass, 2025). Literature education is therefore both a productive site for AI experimentation and a discipline that must guard carefully against reducing interpretation to computation ("Digital Humanities, AI as a Tool," 2025). In Nigeria, this tension is compounded by uneven infrastructure, inconsistent policy guidance, and wide disparities in digital literacy among lecturers and students (Omai, 2024; "Artificial Intelligence Awareness and Adoption Patterns," 2025). Higher education institutions in the country are only beginning to grapple with what AI adoption means for the humanities, even as students increasingly bring AI-generated content, translations, and summaries into literature classrooms ("Artificial Intelligence in Nigerian Higher Education," 2025).

The central problem this paper addresses is the absence of a coherent framework connecting institutional readiness, policy direction, and pedagogic practice in Nigerian literature education ("A Review of Artificial Intelligence," 2024). Much of the existing literature treats AI adoption in education as a general phenomenon, with few studies examining literary pedagogy specifically or Nigerian tertiary institutions in particular (Zawacki-Richter et al., 2019). This paper therefore examines how AI is transforming the teaching and learning of literature in higher education, guided by three questions: How ready are Nigerian higher education institutions to integrate AI into literary studies? What policy and ethical frameworks are needed to guide this integration responsibly? And what pedagogic futures can be imagined for literature education that neither rejects nor uncritically embraces AI? Its significance lies in offering literature educators, policymakers, and curriculum planners a grounded starting point for reimagining literary pedagogy for the AI era, without surrendering the humanistic and culturally rooted core of the discipline (Zeide, 2019).

2.0 Conceptual and Theoretical Perspectives

2.1 Artificial Intelligence in Education

AI in education refers broadly to computational systems capable of performing tasks that traditionally required human intelligence—reasoning, pattern recognition, and language generation—applied to teaching and learning contexts (Zhang & Aslan, 2021). Its evolution has moved through several phases: early intelligent tutoring systems, learning analytics platforms, and now generative AI tools capable of producing original text, summaries, and feedback (Zeide, 2019). Applications in higher education span personalized learning pathways, automated assessment, administrative efficiency, and, increasingly, content generation that touches directly on disciplines like literature (Zawacki-Richter et al., 2019; "Faculty Artificial Intelligence Literacy," 2026).

2.2 Literature Education

Literature education aims to cultivate close reading, critical interpretation, cultural awareness, and imaginative empathy in students (Rosenblatt, 1995). Its traditional approaches—lecture-based exposition, textual explication, and essay-based assessment—have long privileged sustained human engagement with the text (Iser, 1978). These approaches remain central even as digital tools

reshape how texts are accessed, annotated, and shared among students and instructors ("Digital Humanities in Literary Studies," n.d.).

2.3 Digital Humanities

Digital humanities (DH) is the interdisciplinary field where computational methods meet humanistic inquiry, encompassing textual analysis, network mapping, and large-scale corpus study ("Digital Humanities in Literary Studies," n.d.). AI has become deeply entwined with DH, enabling scholars to detect stylistic patterns, attribute authorship, and trace thematic trends across vast bodies of literary text at a scale unreachable by close reading alone ("Digital Humanities, AI as a Tool," 2025).

2.4 Theoretical Framework

This paper draws on three complementary theories to explain AI-enhanced literary learning. Constructivism holds that learners actively build knowledge through experience, a process AI can support by offering adaptive, learner-paced textual scaffolding. Connectivism, developed by Siemens, extends this by framing learning as the capacity to navigate distributed networks of information, positioning AI as another node—or increasingly, an active participant—within a learner's knowledge network (Siemens, 2005). Reader-response theory, associated with Rosenblatt and Iser, insists that meaning emerges from the transaction between reader and text; AI tools that surface alternative interpretations or sentiment patterns can enrich rather than replace this transaction, provided the reader's own response remains central (Rosenblatt, 1995; Iser, 1978). Together, these three theories support a model of AI-enhanced literary learning in which technology scaffolds, connects, and diversifies interpretation without displacing the human reader as the ultimate maker of meaning ("Context Based Learning," 2023).

3.0 AI and the Transformation of Literature Education

"Books are mirrors: you only see in them what you already have inside you." — Carlos Ruiz Zafón (2004)

AI-assisted textual analysis now allows literature students and scholars to move between close reading and distant reading with unprecedented ease ("Digital Humanities, AI as a Tool," 2025). Natural language processing tools can map recurring motifs, track character networks, and quantify stylistic shifts across a novel or an entire corpus, offering evidence that can support—though never substitute for—interpretive argument ("Digital Humanities in Literary Studies," n.d.). Adaptive learning platforms extend this capability into the classroom, adjusting reading difficulty, pacing, and supplementary material to each student's demonstrated needs, which can be especially valuable in large, under-resourced literature classes typical of Nigerian institutions ("Context Based Learning," 2023).

Personalized instruction through AI also supports literary research by helping students locate, summarize, and cross-reference secondary sources more efficiently, while machine translation tools open access to world literature that would otherwise remain linguistically inaccessible (Zhang & Aslan, 2021). In creative writing, generative AI can serve as a drafting partner, offering prompts, alternative phrasings, or structural suggestions that students may accept, revise, or reject

(Govindaraju, 2025). AI has likewise entered literary criticism itself, with algorithms used to investigate authorship attribution, sentiment across narrative arcs, and cross-cultural patterns in canon formation ("Digital Humanities in Literary Studies," n.d.; "Digital Humanities, AI as a Tool," 2025).

These benefits, however, carry real limitations. AI-generated interpretation can flatten ambiguity into statistical pattern, and models trained on skewed corpora risk reproducing cultural bias rather than illuminating it ("Digital Humanities, AI as a Tool," 2025). Scholars caution that authorship, originality, and bias in training data remain unresolved concerns even as AI-generated text grows more sophisticated (Govindaraju, 2025). The central pedagogical challenge, then, is not whether to use AI in literature education but how to use it in ways that deepen, rather than substitute for, the interpretive labour that defines literary study (Zeide, 2019).

4.0 Institutional Readiness in Nigerian Higher Education

Institutional readiness for AI-enhanced literature education in Nigeria begins with basic infrastructure, and here the picture remains uneven. Studies of Nigerian universities consistently identify unreliable electricity, limited broadband access, and inadequate computer laboratories as persistent barriers to any meaningful AI integration (Omai, 2024; "Artificial Intelligence in Nigerian Higher Education," 2025). A review of readiness across northern Nigerian institutions found that even where pockets of improvement exist, infrastructural deficits remain the most cited obstacle to AI adoption in higher education generally, a finding that applies with equal force to literature departments, which have historically received fewer technology investments than science-based faculties ("A Review of Artificial Intelligence," 2024). Comparable challenges have been documented across Nigeria's technical and vocational institutions, suggesting the problem is systemic rather than isolated to any one discipline ("Artificial Intelligence Adoption for Skills Development," n.d.).

Beyond infrastructure, human capacity presents an equally significant constraint. Many lecturers, including those teaching literature, report limited familiarity with AI tools and receive little structured training in their pedagogical use ("Artificial Intelligence Awareness and Adoption Patterns," 2025). Student digital literacy is similarly uneven, shaped by disparities in prior exposure to computers and the internet, which risks widening rather than narrowing achievement gaps if AI tools are introduced without deliberate scaffolding ("Large Language Models and GenAI in Education," n.d.).

Curriculum structures in most literature departments have not yet been revised to accommodate AI-related competencies, leaving students to encounter these tools informally rather than through guided instruction ("Faculty Artificial Intelligence Literacy," 2026). Administrative support and funding for digital humanities initiatives remain limited, and comparative assessments of Nigerian university types show that AI-related activity, where it exists, tends to cluster in a small number of well-resourced institutions rather than spreading evenly across the sector ("Building Sustainable International Partnerships," 2026). Case examples from Nigerian universities piloting AI-enabled learning analytics and digital literacy programmes point to a viable path forward, but such initiatives remain the exception rather than the rule, underscoring the need for coordinated, sector-wide investment in the infrastructure, training, and curriculum reform that literature education requires ("Artificial Intelligence in Nigerian Higher Education," 2025).

5.0 Policy and Ethical Considerations

Nigeria's draft National Artificial Intelligence Strategy (NAIS), published in 2024 by the National Information Technology Development Agency, sets out five pillars—infrastructure, ecosystem development, sector adoption, responsible AI, and governance—that together offer a national framework within which higher education policy can be situated ("Nigerian National AI Strategy," 2024). Yet the strategy remains in draft form, and few Nigerian universities have translated its principles into institution-level policy governing AI use in teaching and assessment, leaving literature departments to navigate AI adoption without clear institutional guidance ("A Review of Artificial Intelligence," 2024).

Academic integrity is among the most pressing concerns raised by AI adoption. Existing plagiarism frameworks were designed to compare student work against existing texts, but generative AI produces original text that evades conventional plagiarism detection, complicating efforts to distinguish authentic student writing from AI-assisted work ("Reassessing Academic Integrity," 2025). Faculty perspectives on this challenge reveal that policy alone is insufficient without corresponding shifts in assessment design and consistent institutional enforcement ("Examining Academic Integrity Policy," 2025). Broader reviews of cheating and plagiarism in higher education confirm that generative AI has intensified, rather than created, a long-standing integrity problem ("Cheating and Plagiarism in Higher Education Institutions," n.d.). Questions of copyright and authorship further complicate the picture, particularly in creative writing and literary criticism, where the boundary between AI assistance and AI authorship is not always self-evident (Govindaraju, 2025).

Data privacy, algorithmic bias, and responsible AI use round out the ethical terrain literature educators must navigate. Because AI systems reproduce patterns present in their training data, uncritical use of these tools in literary analysis risks privileging dominant, often Western, literary canons over African and other underrepresented traditions—a concern with particular resonance in a Nigerian context ("Digital Humanities, AI as a Tool," 2025). African scholars have begun to press this point further, arguing that AI can either entrench colonial patterns of knowledge production or, if deliberately redirected, become an instrument for decolonising academic writing and inclusive scholarship (Omodan & Marongwe, 2024). UNESCO's guidance on generative AI in education stresses a human-centred approach that safeguards human rights, cultural diversity, and human decision-making even as institutions adopt AI tools (UNESCO, 2025). Assessment itself must also be reconsidered, since take-home essays and literary analyses—the traditional backbone of literature assessment—are now the assignments most vulnerable to undisclosed AI use, requiring literature departments to rethink how they evaluate genuine interpretive engagement ("Examining Academic Integrity Policy," 2025).

6.0 Pedagogic Futures for Literature Education

The most promising pedagogic future for literature education is not one that displaces the teacher but one that reconfigures the classroom around hybrid pedagogy, in which AI functions as a teaching assistant rather than a replacement for human instruction (UNESCO, 2025). AI can support literature teaching by drafting discussion prompts, generating differentiated reading questions, or providing preliminary feedback on drafts, freeing lecturers to focus on the interpretive dialogue that remains uniquely human ("Building Critical AI Literacy," 2025).

Central to this future is critical AI literacy: the capacity to understand, apply, and evaluate AI outputs rather than accept them uncritically ("Generative AI & the Writing Center," n.d.). Literature students who learn to interrogate an AI-generated interpretation—asking what the tool privileged, what it missed, and why—develop sharper critical faculties than those who either avoid AI entirely or accept its output at face value ("Faculty Artificial Intelligence Literacy," 2026). Collaborative learning models that pair AI feedback with peer review have shown particular promise, with students relying on AI for surface-level revision while turning to peers and instructors for deeper conceptual and disciplinary engagement ("Writing With Machines and Peers," 2025).

Human creativity remains the irreducible core of literary study, and pedagogic futures must protect space for the slow, uncertain work of interpretation that no algorithm can shortcut (Rosenblatt, 1995; Iser, 1978). The future literature classroom is therefore likely to be a blended space, combining traditional close reading with AI-assisted research and analysis, supported by assessment redesigned to reward process, reflection, and disclosed AI use rather than polished final products alone ("Examining Academic Integrity Policy," 2025).

7. Recommendations

Based on the preceding analysis, the following recommendations are proposed for Nigerian higher education institutions:

1. Develop clear, discipline-specific AI policies for literature and humanities departments, consistent with national guidance such as the NAIS ("Nigerian National AI Strategy," 2024).

2. Train lecturers in AI literacy and pedagogically sound AI integration, not merely the technical operation of tools.

3. Revise literature curricula to explicitly teach critical AI literacy alongside traditional interpretive skills.

4. Invest in infrastructure, including reliable electricity, internet access, and computer laboratories, prioritizing equity across institution types.

5. Promote ethical AI use through institutional guidelines addressing academic integrity, copyright, and data privacy.

8.0 Conclusion

This paper has argued that artificial intelligence is already reshaping literature education, and that Nigerian higher education institutions must respond deliberately rather than reactively. Institutional readiness, drawn from the state of infrastructure, human capacity, and curriculum design, remains uneven, while policy frameworks, though emerging at the national level, have yet to reach the departmental level where literature is actually taught. What is clear is that AI should complement, not replace, the human interpretation that lies at the heart of literary study. Literature education must remain culturally grounded, drawing on African literary traditions and interpretive practices—including indigenous oral forms now being reimagined through AI (Idowu & Abbass,

2025)—even as it engages new technologies. Institutions must prepare both teachers and students, equipping them with the critical AI literacy necessary to use these tools meaningfully rather than superficially. The future, this paper contends, belongs not to unchecked automation nor to outright rejection of AI, but to balanced integration guided by pedagogy, ethics, and cultural context.

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AUTOMATION TO AUGMENTATION: ENHANCING PRE-SERVICE TEACHERS' READINESS THROUGH AI-AUGMENTED INTELLIGENT TUTORING SYSTEMS IN HIGHER EDUCATION IN KWARA STATE

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Abstract

The integration of Artificial Intelligence (AI) in education has shifted from mere automation to augmentation, emphasizing the enhancement of teaching and learning through intelligent systems. This study investigated the readiness of pre-service teachers to utilize AI-augmented Intelligent Tutoring Systems (ITS) in higher education institutions in Kwara State, Nigeria. Specifically, the study examined levels of awareness, readiness, accessibility, and perceived usefulness of AI technologies, as well as the relationship between awareness and readiness. A descriptive survey research design was adopted, with a sample of 400 pre-service teachers selected from a population of 16,500 using stratified random sampling. Data were collected through a structured questionnaire titled AI-Augmented Learning Readiness Questionnaire (AILRQ), validated by experts and yielding a reliability coefficient of 0.82. Descriptive statistics (mean and standard deviation) and inferential statistics (Pearson Product Moment Correlation) were used for data analysis at a 0.05 level of significance. Findings revealed a high level of awareness (Mean = 3.45) and perceived usefulness (Mean = 3.62) of AI technologies among pre-service teachers. However, readiness to utilize AI-augmented ITS (Mean = 2.98) and accessibility to digital infrastructure (Mean = 2.76) were found to be moderate, indicating a gap between awareness and practical competence. Furthermore, a significant positive relationship ($r = 0.62$, $p < 0.05$) was established between awareness and readiness. The study concludes that while pre-service teachers demonstrate strong awareness and positive perceptions of AI in education, their readiness is constrained by limited training and infrastructural challenges. It recommends targeted capacity-building initiatives, improved digital infrastructure, and policy-driven support to bridge the gap between awareness and effective utilization, thereby fostering the successful integration of AI-augmented systems in teacher education.

Keywords: Artificial Intelligence (AI), AI-augmented Systems, Pre-Service Teacher, Automation, Augmentation, Readiness, Higher Education

Introduction

The rapid advancement of Artificial Intelligence (AI) has ushered in transformative changes across various sectors, with education emerging as one of the most significantly impacted domains. In recent years, the application of AI in education has evolved from simple automation of administrative and instructional processes to more sophisticated forms of augmentation that enhance human capabilities in teaching and learning. This paradigm shift from automation to augmentation emphasizes the collaborative interaction between human intelligence and machine

intelligence in creating more effective, personalized, and adaptive learning environments (Luckin, 2018; Holmes, Bialik, & Fadel, 2019).

Traditionally, educational technologies were primarily designed to automate routine tasks such as grading, attendance tracking, and content delivery. However, contemporary AI-driven systems now focus on augmenting the roles of teachers by providing real-time feedback, predictive analytics, and personalized instructional support. According to UNESCO (2021), AI has the potential to redefine teaching and learning ecosystems by enabling more inclusive, equitable, and learner-centered education systems. This transformation is particularly relevant in teacher education, where pre-service teachers must be equipped with the competencies required to function effectively in digitally mediated and AI-supported classrooms.

One of the most promising applications of AI in education is the development and deployment of Intelligent Tutoring Systems (ITS). These systems simulate one-on-one tutoring by adapting instructional content to the needs, pace, and abilities of individual learners (Woolf, 2010). ITS have been shown to improve student learning outcomes by providing immediate feedback, scaffolding learning experiences, and supporting mastery learning approaches (VanLehn, 2011). Beyond student learning, ITS also serve as valuable tools for teacher preparation by exposing pre-service teachers to innovative pedagogical practices and data-driven instructional strategies.

Despite the growing global adoption of AI technologies in education, developing countries such as Nigeria face unique challenges that hinder effective implementation. These challenges include inadequate technological infrastructure, limited access to digital resources, insufficient training opportunities, and the absence of comprehensive policy frameworks to guide AI integration in education (Adeleke & Eze, 2022). Consequently, while awareness of AI tools may be increasing among pre-service teachers, their readiness to effectively utilize such technologies remains a critical concern.

In the Nigerian context, several scholars have examined the integration of technology in education and its implications for teacher preparation. For instance, Yusuf (2012) emphasizes that the successful integration of Information and Communication Technology (ICT) in education depends largely on teachers' competence and readiness. Similarly, Bolaji (2015) highlights that teacher education programs in Nigeria must prioritize digital literacy and pedagogical innovation to meet the demands of the 21st-century classroom. Ahmed (2018) further argues that the adoption of emerging technologies, including AI, requires a shift in both instructional design and institutional support systems. Adedokun-Shittu and Shittu (2013) also underscore the importance of accessibility and usability of digital technologies in enhancing teaching and learning outcomes. Their study reveals that while educators may have positive attitudes toward technology, actual utilization is often constrained by infrastructural and institutional barriers. This suggests that readiness for AI adoption extends beyond individual willingness to include systemic and environmental factors.

Furthermore, the concept of readiness in the context of AI integration encompasses multiple dimensions, including awareness, technical competence, accessibility, and perceived usefulness. According to Tondeur et al., (2017), pre-service teachers' readiness to integrate technology is influenced by their exposure to digital tools during training, the availability of institutional support, and their beliefs about the value of technology in education. In line with this, Siemens and Baker

(2012) note that AI-driven learning analytics can play a crucial role in enhancing instructional decision-making, thereby supporting both teachers and learners in achieving better outcomes.

The shift toward AI-augmented education also aligns with key learning theories that emphasize personalization and learner-centered approaches. Cognitive Theory supports the idea that learners actively construct knowledge through interaction with their environment, while Adaptive Learning Theory highlights the importance of tailoring instruction to individual learner needs. Mastery Learning Theory, on the other hand, emphasizes the need for learners to achieve a high level of understanding before progressing to more advanced content (Bloom, 1968). AI-powered ITS effectively operationalize these theories by providing adaptive, personalized, and competency-based learning experiences.

Given these developments, there is a pressing need to examine how AI-augmented Intelligent Tutoring Systems can be leveraged to enhance the readiness of pre-service teachers, particularly in contexts like Nigeria where technological adoption is still evolving. Understanding the interplay between awareness, readiness, accessibility, and institutional support is crucial for designing effective strategies for AI integration in teacher education. Therefore, this study seeks to investigate the extent to which AI-augmented ITS can enhance pre-service teachers' readiness in Nigerian higher education institutions. By addressing the gap between awareness and practical competence, this research contributes to the broader discourse on reimagining teaching and learning ecosystems in the AI era. It also provides empirical insights that can inform policy, practice, and future research in the field of educational technology.

Purpose of the Study

The main purpose of this study is to examine the readiness of pre-service teachers to utilize AI-augmented Intelligent Tutoring Systems in higher institutions in Kwara State. Specifically, the study seeks to:

1. Examine the level of awareness of Artificial Intelligence technologies among pre-service teachers in higher institutions in Kwara State.

2. Assess the level of readiness of pre-service teachers to utilize AI-augmented Intelligent Tutoring Systems in teaching and learning.

3. Determine the extent of accessibility to AI technologies and digital infrastructure among pre-service teachers.

4. Evaluate the perceived usefulness of AI-augmented Intelligent Tutoring Systems in enhancing teaching and learning among pre-service teachers.

5. Examine the relationship between pre-service teachers' awareness of Artificial Intelligence technologies and their readiness to utilize AI-augmented Intelligent Tutoring Systems.

Research Questions

The study is guided by the following research questions:

1. What is the level of awareness of Artificial Intelligence technologies among pre-service teachers in higher institutions in Kwara State?

2. What is the level of readiness of pre-service teachers to utilize AI-augmented Intelligent Tutoring Systems in teaching and learning?

3. To what extent do pre-service teachers have access to AI technologies and digital infrastructure in their institutions?

4. What is the perceived usefulness of AI-augmented Intelligent Tutoring Systems in enhancing teaching and learning among pre-service teachers?

Research Hypothesis

The study tests the following null hypothesis:

$H_0$1: There is no significant relationship between pre-service teachers' awareness of Artificial Intelligence technologies and their readiness to utilize AI-augmented Intelligent Tutoring Systems in higher institutions in Kwara State.

Methodology

This study adopted a descriptive survey research design to investigate the readiness of pre-service teachers to utilize AI-augmented Intelligent Tutoring Systems (ITS) in higher institutions in Kwara State. The population of the study comprised all pre-service teachers enrolled in Colleges of Education and Faculties of Education in universities across Kwara State. These individuals are considered suitable for the study because they represent future educators who are expected to integrate emerging technologies, including Artificial Intelligence, into their teaching practices. Given the estimated population of 16,500 pre-service teachers in Kwara State, the sample was determined using the Taro Yamane formula, which yielded a sample size of 400 pre-service teachers.

A stratified random sampling technique was employed to ensure adequate representation of pre-service teachers across different institutions and levels of study. The population was first stratified based on institution type (Colleges of Education and Universities), and thereafter, respondents were randomly selected from each stratum proportionately. Data for the study were collected using a structured questionnaire titled "AI-Augmented Learning Readiness Questionnaire (AILRQ)". The instrument was designed by the researcher, It consisted of two sections: Section A captured demographic information of respondents, while Section B contained items measuring key variables such as awareness of AI technologies, readiness to use Intelligent Tutoring Systems, accessibility to digital resources, and perceived usefulness of AI in education. The items were structured on a four-point Likert scale ranging from Strongly Agree (4), Agree (3), Disagree (2), to Strongly Disagree (1), allowing respondents to express varying degrees of agreement.

To ensure the validity of the instrument, the questionnaire was subjected to expert review by specialists in Educational Technology and Measurement and Evaluation. These experts examined the instrument for content relevance, clarity, and alignment with the research objectives. The reliability of the instrument was determined through a pilot study conducted among a group of pre-service teachers outside the main study sample. The data obtained from the pilot test were analyzed using Cronbach's Alpha reliability coefficient, which yielded a value of 0.82. This value exceeds the acceptable threshold of 0.70, indicating that the instrument has a high level of internal consistency and is reliable for data collection.

The data collected were analyzed using both descriptive and inferential statistical methods. Descriptive statistics, including mean and standard deviation, were used to answer the research questions by summarizing the responses of participants. A decision rule was established such that a mean score of 2.50 and above indicated agreement, while a mean score below 2.50 indicated disagreement. For the testing of the hypothesis, Pearson Product Moment Correlation (PPMC) was employed to determine the relationship between pre-service teachers' awareness of AI technologies and their readiness to utilize AI-augmented Intelligent Tutoring Systems. The hypothesis was tested at a 0.05 level of significance.

Results

Research Question 1:

What is the level of awareness of Artificial Intelligence technologies among pre-service teachers in higher institutions in Kwara State?

Table 1: ***Mean Analysis of Awareness of AI Technologies***

Items	Mean	Std. Dev	Decision
I am aware of AI tools used in education	3.52	0.68	Agree
I have heard about Intelligent Tutoring Systems	3.41	0.73	Agree
I am familiar with AI applications in teaching	3.38	0.75	Agree
AI is increasingly used in modern classrooms	3.49	0.70	Agree
Cluster Mean	**3.45**	**0.72**	**High**

The results in Table 1 indicate that pre-service teachers have a high level of awareness of AI technologies, with a cluster mean of 3.45. This suggests that pre-service teachers are generally familiar with AI concepts and their applications in education. The findings imply that exposure to AI-related information is increasing among pre-service teachers in higher institutions in Kwara State.

Research Question 2:

What is the level of readiness of pre-service teachers to utilize AI-augmented Intelligent Tutoring Systems?

Table 2: ***Mean Analysis of Readiness to Use AI-Augmented ITS***

Items	Mean	Std. Dev	Decision
I can effectively use AI tools for learning	2.95	0.82	Agree
I am confident in integrating ITS into teaching	2.87	0.85	Agree
I have received training on AI tools	2.76	0.88	Agree
I am willing to adopt AI technologies in teaching	3.34	0.74	Agree

Cluster Mean	**2.98**	**0.81**	**Moderate**

Table 2 reveals that the readiness of pre-service teachers to utilize AI-augmented ITS is moderate (Mean = 2.98). Although respondents show willingness to adopt AI technologies, their confidence and training levels are relatively lower. This indicates a gap between awareness and actual readiness for implementation.

Research Question 3:

To what extent do pre-service teachers have access to AI technologies and digital infrastructure?

Table 3: ***Mean Analysis of Accessibility to AI Technologies***

Items	Mean	Std. Dev	Decision
I have access to internet-enabled devices	3.02	0.84	Agree
My institution provides access to AI tools	2.61	0.90	Agree
Internet connectivity is reliable in my institution	2.48	0.92	Disagree
I can easily access digital learning platforms	2.93	0.86	Agree
Cluster Mean	**2.76**	**0.88**	**Moderate**

The results in Table 3 show that accessibility to AI technologies is moderate (Mean = 2.76). While pre-service teachers have some level of access to digital devices and platforms, challenges such as unreliable internet connectivity and limited institutional provision of AI tools persist.

Research Question 4:

What is the perceived usefulness of AI-augmented Intelligent Tutoring Systems?

Table 4: Mean Analysis of Perceived Usefulness of AI (N = 400)

Items	Mean	Std. Dev	Decision
AI improves learning outcomes	3.64	0.66	Agree
ITS provides personalized learning experiences	3.58	0.70	Agree
AI enhances teaching effectiveness	3.67	0.65	Agree
AI supports student engagement	3.59	0.69	Agree
Cluster Mean	**3.62**	**0.69**	**High**

Table 4 indicates that pre-service teachers perceive AI-augmented ITS as highly useful (Mean = 3.62). Respondents strongly agree that AI enhances both teaching effectiveness and student learning experiences. This suggests a positive attitude toward AI adoption despite existing challenges.

Hypothesis Testing

$H_0$1: There is no significant relationship between pre-service teachers' awareness of AI technologies and their readiness to utilize AI-augmented Intelligent Tutoring Systems.

Table 5: Pearson Product Moment Correlation (PPMC) Analysis

Variables	N	Mean	Std. Dev	r-value	p-value	Decision
Awareness of AI	400	3.45	0.72			
Readiness to Use ITS	400	2.98	0.81	0.62	0.000	Significant

The results in Table 5 show a strong positive relationship (r = 0.62) between awareness of AI technologies and readiness to utilize AI-augmented ITS. The p-value (0.000) is less than the significance level of 0.05, indicating that the relationship is statistically significant. Therefore, the null hypothesis is rejected, and the alternative hypothesis is accepted. This implies that increased awareness of AI technologies significantly enhances pre-service teachers' readiness to adopt AI-augmented Intelligent Tutoring Systems.

Discussion of Findings

The findings of this study provide important insights into the readiness of pre-service teachers to utilize AI-augmented Intelligent Tutoring Systems (ITS) within higher education institutions. The discussion is structured in line with the research questions and hypothesis, while drawing connections to existing literature both within and outside Nigeria.

The first finding of the study revealed that pre-service teachers possess a high level of awareness of Artificial Intelligence technologies (Mean = 3.45). This suggests that exposure to AI concepts and tools is increasing among future educators, likely due to the proliferation of digital technologies and online learning platforms. This finding is consistent with the work of Yusuf (2012), who noted that awareness of emerging technologies among Nigerian pre-service teachers has improved significantly due to increased access to digital information. Similarly, Holmes et al., (2019) argued that global awareness of AI in education has grown rapidly, particularly with the rise of digital transformation initiatives in education systems.

However, this finding contrasts with earlier studies such as Adedokun-Shittu and Shittu (2013), which reported relatively low awareness levels among educators in developing contexts due to limited exposure and infrastructural challenges. The discrepancy may be attributed to recent technological advancements and increased internet penetration, which have improved access to information. Nonetheless, awareness alone does not guarantee effective utilization, as evidenced by subsequent findings in this study.

The second finding indicated that pre-service teachers' readiness to utilize AI-augmented ITS is moderate (Mean = 2.98). This suggests that although respondents are aware of AI technologies, they lack sufficient competence, confidence, and training to effectively integrate these tools into teaching and learning processes. This aligns with the findings of Tondeur et al., (2017), who

emphasized that teacher readiness for technology integration is often limited by inadequate training and lack of practical exposure during teacher education programs.

In the Nigerian context, Bolaji (2015) also highlighted that teacher preparation programs have not fully integrated digital and AI competencies into their curricula, thereby limiting readiness for modern classroom demands. Similarly, Ahmed (2018) noted that the adoption of emerging technologies in education requires not only awareness but also structured training and institutional support.

On the contrary, some studies in developed contexts have reported higher levels of readiness among pre-service teachers. For instance, Pane et al., (2015) found that exposure to adaptive learning systems significantly improves teachers' readiness and confidence in using AI tools. The difference between these findings and the present study may be attributed to disparities in infrastructure, training opportunities, and policy support between developed and developing countries.

The third finding revealed that accessibility to AI technologies and digital infrastructure is moderate (Mean = 2.76), with notable challenges such as unreliable internet connectivity and limited institutional provision of AI tools. This finding is consistent with Adeleke and Eze (2022), who identified infrastructural deficits as a major barrier to digital transformation in African education systems. Similarly, Adedokun-Shittu and Shittu (2013) emphasized that access to technology remains a critical factor influencing its effective utilization in teaching and learning.

However, this finding contrasts with studies conducted in technologically advanced environments, where access to digital infrastructure is less of a constraint. Siemens and Baker (2012) reported that institutions with robust technological infrastructure are better positioned to implement AI-driven learning systems effectively. The disparity highlights the need for context-specific strategies in implementing AI in education, particularly in resource-constrained environments like Nigeria.

The fourth finding showed that pre-service teachers perceive AI-augmented ITS as highly useful (Mean = 3.62). Respondents strongly agreed that AI enhances teaching effectiveness, supports personalized learning, and improves student engagement. This finding is in line with Woolf (2010) and VanLehn (2011), who demonstrated that Intelligent Tutoring Systems significantly improve learning outcomes through adaptive feedback and individualized instruction.

Furthermore, Luckin (2018) argued that AI has the potential to augment human intelligence by providing insights that enhance teaching and learning processes. The high perceived usefulness observed in this study suggests that pre-service teachers are positively disposed toward AI technologies, even if they are not fully prepared to use them effectively.

Nevertheless, some scholars caution against over-reliance on AI in education. UNESCO (2021) warns that without proper ethical considerations, AI may introduce issues such as data privacy concerns, algorithmic bias, and over-dependence on technology. This perspective suggests that while AI is perceived as useful, its implementation must be carefully managed to avoid unintended consequences.

The hypothesis testing revealed a significant positive relationship between awareness of AI technologies and readiness to utilize AI-augmented ITS ($r = 0.62$, $p < 0.05$). This implies that increased awareness significantly influences readiness among pre-service teachers. This finding supports the assertion by Yusuf (2012) that awareness is a critical precursor to technology adoption

in education. It also aligns with Rogers' Diffusion of Innovation Theory, which posits that awareness is the first stage in the adoption process.

Similarly, Tondeur et al., (2017) found that teachers who are more aware of technological tools are more likely to develop the competence and confidence needed for integration. However, the moderate level of readiness observed in this study suggests that awareness alone is insufficient. Other factors such as training, accessibility, and institutional support play crucial roles in translating awareness into actual practice.

Conversely, some studies argue that awareness does not always lead to readiness or adoption. For example, Adedokun-Shittu and Shittu (2013) found that despite high awareness levels, many educators were unable to integrate technology effectively due to systemic barriers. This reinforces the idea that readiness is a multifaceted construct that extends beyond awareness.

Overall, the findings of this study underscore the complexity of transitioning from automation to augmentation in education. While pre-service teachers in Nigeria demonstrate high awareness and positive perceptions of AI technologies, their readiness is constrained by infrastructural, institutional, and training-related challenges. This suggests that achieving effective AI integration in education requires a holistic approach that addresses both human and systemic factors.

Conclusion

This study examined the readiness of pre-service teachers in Nigerian higher education institutions to utilize AI-augmented Intelligent Tutoring Systems (ITS) within the evolving paradigm of educational transformation from automation to augmentation. The findings provide compelling evidence that while awareness and perceived usefulness of Artificial Intelligence in education are relatively high among pre-service teachers, their actual readiness to effectively utilize these technologies remains moderate.

The high level of awareness observed indicates that pre-service teachers are increasingly exposed to AI concepts and applications, reflecting the growing influence of digital technologies in education. Similarly, the strong perception of usefulness suggests that these future educators recognize the potential of AI-augmented systems to enhance teaching effectiveness, support personalized learning, and improve student engagement. These positive dispositions are critical foundational elements for the successful adoption of AI in education.

However, the study also reveals a significant gap between awareness and readiness. Despite their familiarity with AI technologies, pre-service teachers lack sufficient competence, practical experience, and confidence to fully integrate AI-augmented ITS into teaching and learning processes. This gap is further compounded by moderate levels of accessibility to digital infrastructure, including unreliable internet connectivity and limited institutional support. These challenges highlight the systemic constraints that hinder the transition from theoretical awareness to practical implementation.

The significant positive relationship identified between awareness and readiness underscores the importance of knowledge as a driver of technology adoption. However, the findings also demonstrate that awareness alone is not sufficient to guarantee effective utilization. Readiness is a multidimensional construct that requires not only cognitive awareness but also technical skills, institutional backing, and enabling environments.

In the context of the broader shift from automation to augmentation, this study emphasizes that the integration of AI in education should not be viewed merely as a technological upgrade but as a pedagogical transformation. AI-augmented Intelligent Tutoring Systems have the potential to redefine the roles of teachers by positioning them as facilitators, decision-makers, and co-creators of knowledge alongside intelligent systems. For this potential to be fully realized, there must be deliberate and sustained efforts to equip pre-service teachers with the necessary competencies and resources.

The successful adoption of AI-augmented ITS in Nigerian higher education depends on a holistic approach that addresses both human and systemic factors. While the current level of awareness and positive perception provides a strong foundation, bridging the gap between awareness and readiness requires targeted interventions in training, infrastructure development, and policy formulation. By doing so, educational institutions can effectively transition from automation to augmentation, thereby fostering a more innovative, inclusive, and future-ready teaching and learning ecosystem.

Recommendations

1. Given the high level of awareness of AI technologies among pre-service teachers, it is recommended that teacher education institutions should sustain and deepen this awareness by incorporating structured AI literacy programs, seminars, and awareness campaigns into their academic calendar.

2. In response to the moderate level of readiness observed, it is recommended that institutions should prioritize hands-on training and capacity-building initiatives focused on AI-augmented Intelligent Tutoring Systems. This includes practical workshops, micro-teaching sessions using AI tools, and integration of AI applications into teaching practice to enhance competence and confidence.

3. Considering the moderate accessibility to AI tools and existing infrastructural challenges, it is recommended that government and institutional stakeholders should improve access to digital infrastructure, including reliable internet connectivity, provision of AI-enabled platforms, and well-equipped ICT centers to support seamless adoption of AI technologies.

4. Given the high perceived usefulness of AI technologies, it is recommended that institutions should leverage this positive perception by promoting the practical application of AI tools in teaching and learning. This can be achieved by embedding AI-supported instructional strategies into coursework and encouraging innovative teaching approaches that utilize Intelligent Tutoring Systems.

5. In light of the significant relationship between awareness and readiness, it is recommended that policymakers and educators should adopt a holistic approach that links awareness initiatives with skill development and institutional support. This means that awareness programs should be complemented with training, access to tools, and supportive policies to effectively translate awareness into actual readiness and utilization.

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ARTIFICIAL INTELLIGENCE IN EDUCATION: OPPORTUNITIES, CHALLENGES, AND FUTURE DIRECTIONS FOR TEACHING AND LEARNING IN NIGERIAN SECONDARY SCHOOLS

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Abstract

The integration of Artificial Intelligence (AI) into secondary education is changing how teaching, assessment, and school administration are carried out around the world. In Nigeria, secondary education provides an important link between basic education and tertiary study, technical and vocational training, or entry into the workforce. However, the system continues to face serious structural pressures, including very high student to teacher ratios, shortages of qualified STEM teachers, limited funding, and major differences between urban and rural schools. Artificial Intelligence in Education (AIED), including adaptive learning platforms, intelligent tutoring systems, generative language models, and automated learning analytics, could help personalize learning, reduce routine marking and administrative work, and support schools where teaching capacity is limited. At the same time, adoption in Nigeria faces practical challenges such as unreliable electricity, expensive broadband, gaps in teachers' digital skills, and the absence of clear policy frameworks. This monograph examines these opportunities and challenges and sets out practical policy directions for making AI adoption more equitable, ethical, and sustainable.

Keywords: Artificial Intelligence in Education (AIED), Adaptive Learning Systems, Digital Literacy, Structural Infrastructure Deficit, Educational Technology Governance, Pedagogical Transformation.

Introduction

Education is widely recognized as a major driver of social mobility, human capital development, and national growth. In Sub Saharan Africa, and particularly in Nigeria, secondary education plays a central role. It connects primary education with higher academic study, technical and vocational training, and entry into the workforce. Despite this role, Nigerian secondary schools continue to operate under considerable pressure. Public schools across the 36 states and the Federal Capital Territory regularly deal with overcrowded classrooms, with student to teacher ratios often above 60:1 and sometimes reaching 100:1 in densely populated areas such as Lagos and Kano (Gambo et al., 2026; UNESCO, 2023). These pressures are made worse by limited funding, shortages of qualified subject teachers, especially in Science, Technology, Engineering, and Mathematics (STEM), outdated learning materials, and wide differences in educational resources between well served urban communities and rural areas.

At the same time, education systems around the world are being reshaped by Artificial Intelligence (AI). Artificial Intelligence in Education (AIED) covers the use of technologies such as machine learning (ML), natural language processing (NLP), computer vision, and neural networks to support and improve teaching and learning activities (Hwang & Chien, 2022). AI is moving beyond small scale experiments and becoming part of the wider education technology landscape.

Intelligent Tutoring Systems (ITS) can provide students with immediate, individualized support; adaptive learning systems can adjust learning activities according to a student's progress; generative AI can assist with lesson planning and differentiated instruction; and predictive analytics can help identify learners who may be at risk of falling behind (ZawackiRichter et al., 2019; Holmes et al., 2023).

For Nigeria, where education expansion is constrained by funding pressures and a rapidly growing population, these technologies offer an opportunity to widen access to quality instruction. Scalable AI tools could support more personalized learning for secondary school students across different locations, including communities that have limited access to specialist teachers (Ogunlade & Adebayo, 2025). However, introducing technology into education is not straightforward. AI systems used in Nigerian schools would have to operate within difficult conditions, including an unreliable electricity supply, high Internet data costs, gaps in teachers' digital skills, limited integration with the local curriculum, and weak regulatory structures (Akinfalabi, 2025; Cookey & Nwankwo, 2025).

This monograph examines the opportunities, practical realities, challenges, and strategic options for integrating AI into Nigerian secondary schools. Drawing on empirical findings, theoretical perspectives, and recent literature from 2021 to 2026, it provides policymakers, school leaders, EdTech developers, and researchers with a practical framework for pursuing AI adoption in a way that is equitable, ethical, and sustainable.

Theoretical & Conceptual Framework

To assess the use of AI in Nigerian secondary classrooms, it is helpful to look at the main types of educational AI tools as well as the learning theories that explain how students may interact with them.

Taxonomy of AI Modalities in Secondary Education

Educational AI applications used in secondary schools can be grouped into four main areas:

1. Adaptive Learning Systems (ALS): These systems use methods such as Bayesian Knowledge Tracing (BKT) and Item Response Theory (IRT) to track student responses, estimate levels of mastery, and adjust the difficulty, pace, and presentation of learning materials (Yahaya et al., 2024). For example, a platform may provide additional practice when a student struggles with a geometry quiz or move the student to more advanced work after mastery is demonstrated
2. Intelligent Tutoring Systems (ITS): These systems are designed to represent subject knowledge, student learning needs, and teaching strategies. They can guide students through problems, provide hints in natural language, and give immediate feedback in subjects such as Physics, Chemistry, and English Grammar (Gambo et al., 2026).
3. Generative AI and Large Language Models (LLMs): These deep learning models, including GPT 4, Claude, and specialized open source LLMs, can generate text, explanations, assessment questions, and lesson plans. In secondary schools, they can support teachers with administrative and instructional materials and can also provide students with a conversational way to explore questions and ideas (Cookey & Nwankwo, 2025)

4. Educational Data Mining and Predictive Analytics: These tools bring together information such as student performance, attendance, and engagement to help schools identify likely academic outcomes, recognize early signs of dropout risk, and make better use of available resources (Nwuke & Yellowe, 2024).

Theoretical Grounding: Socio-Constructivism and Cognitive Load Theory

The use of AI in secondary education can be linked to Vygotsky's (1978) Socio Constructivist Theory, particularly the idea of the Zone of Proximal Development (ZPD). The ZPD describes the gap between what a learner can do independently and what the learner can achieve with appropriate support from a More Knowledgeable Other (MKO). In a Nigerian public classroom with around 70 students, it is difficult for one teacher to provide this level of individual support to every learner at the same time. Adaptive AI platforms can provide some of that support by acting as a digital MKO. By responding to a student's work, an AI system can offer targeted hints, simpler explanations, analogies, or step by step guidance. This can help keep students working at an appropriate level and reduce the risk of both overload and disengagement (Akinfalabi, 2025).

Sweller's (1988) Cognitive Load Theory (CLT) also helps explain how AI may support learning. Students working with difficult concepts, such as chemical bonding or quadratic equations, can struggle when the same material is presented to everyone without considering differences in prior knowledge and working memory. Adaptive AI systems can break complex topics into smaller learning activities and present examples that are better suited to a student's existing knowledge. This can reduce unnecessary cognitive demands and leave more mental capacity for understanding new concepts and building long term knowledge (Yahaya et al., 2024).

Opportunities For Teaching & Learning in Nigerian Secondary Schools

Used carefully, AI could help address some of the long standing problems in Nigerian secondary education. Its potential benefits include more individualized teaching, reduced administrative workload, support for schools with teacher shortages, and better language support.

Personalization of Instruction in Overcrowded Classrooms

Overcrowding is one of the most serious barriers to quality teaching in Nigerian public secondary schools. In state owned schools across Lagos, Kano, Oyo, and Kaduna, classes often have 60 to 80 students or more per teacher (UNESCO, 2023). In a classroom of this size, teachers have little choice but to teach toward the average learner. Stronger students may not receive enough challenge, while students who need more support can fall further behind. Over time, this can contribute to frustration and poor examination performance.

Adaptive learning systems can help by giving students different learning pathways within the same class. For example, an adaptive mathematics application could identify that an SS2 student struggling with trigonometry has gaps in basic algebra. Instead of simply repeating the same trigonometry lesson, the system could provide targeted remedial activities and allow the student to strengthen those foundations before returning to the grade level work (Yahaya et al., 2024; Gambo et al., 2026). Evaluations of adaptive learning platforms in West African pilot programmes

have also reported improvements in student retention and examination pass rates compared with traditional lecture based approaches.

Mitigating Educator Workload and Automating Administrative Operations

Secondary school teachers in Nigeria often carry a heavy administrative workload in addition to their teaching responsibilities. They may have to prepare weekly lesson notes based on the Nigerian Educational Research and Development Council (NERDC) curriculum, set tests, mark large numbers of continuous assessment scripts, maintain attendance registers, and prepare termly reports (Cookey & Nwankwo, 2025).

Generative AI and automated assessment tools could reduce some of this workload. Language models can help teachers prepare lesson plans, including objectives, teaching aids, and assessment questions, while computer vision and Optical Character Recognition (OCR) can support the marking of multiple choice tests and some handwritten short answers (Nwuke & Yellowe, 2024). If routine administrative work is reduced, teachers can spend more time on activities that require direct human involvement, such as counselling students, supporting group work, and responding to emotional or behavioural needs.

Bridging STEM Educator Shortages in Rural and Marginalized Communities

Nigeria also has a serious imbalance in the distribution of qualified teachers. Specialist STEM teachers in subjects such as Physics, Chemistry, Further Mathematics, and Computer Science are concentrated largely in urban and private schools, leaving many rural and peri urban public schools understaffed (Gambo et al., 2026). In some rural schools, teachers trained in humanities are required to teach science subjects, which can affect instructional quality and student performance in examinations such as the West African Senior School Certificate Examination (WASSCE) and the Unified Tertiary Matriculation Examination (UTME).

Intelligent Tutoring Systems (ITS) and virtual laboratories could provide useful support in schools where specialist teachers are not available. Offline capable AI tutors could guide students through physics experiments, chemical reaction simulations, and mathematical problems, while providing immediate feedback and step by step explanations. AI would not replace the role of a teacher, but it could provide additional instructional support and help rural students maintain access to STEM learning opportunities (Ogunlade & Adebayo, 2025).

Language Scaffolding and Contextualized Learning

Nigeria's linguistic diversity, with more than 500 indigenous languages, creates additional challenges for secondary education. English is the official language of instruction from upper primary school onward, but many secondary students, particularly in rural communities, have limited proficiency in English. This can make it harder for them to understand difficult concepts in subjects such as Biology, Economics, and Government.

Natural language processing (NLP) tools could provide translation and language support in real time. Emerging EdTech applications can translate scientific terms and explanations from English

into major Nigerian languages such as Hausa, Yoruba, and Igbo, as well as some local dialects. This could help students understand difficult ideas in a familiar language while also building their English vocabulary (Akinfalabi, 2025). Speech recognition tools could also support pronunciation, oral reading, and essay writing by giving students repeated feedback as they practise.

Key Challenges to AI Integration in Nigerian Secondary Schools

The potential benefits of AI are significant, but putting these systems into practice in Nigerian secondary schools will involve major infrastructure, financial, human capacity, policy, and ethical challenges. If these issues are not addressed, technology projects may fail or could make existing inequalities worse.

Table 1: Comprehensive Matrix of Barriers to AI Adoption in Nigerian Secondary Schools

Domain	Primary Barriers and Manifestations	Operational Impact on Secondary Schools	Key Citations
Infrastructural Deficit	Unreliable national power supply; high cost of diesel or solar backup; limited 4G and 5G network coverage in rural areas; lack of functional ICT laboratories.	Digital equipment cannot be used consistently; software updates may fail; cloud-based AI services may be unavailable in rural schools.	Akinfalabi (2025); Ogunlade and Adebayo (2025)
Human Capital and Pedagogical Gaps	Limited teacher digital skills; inadequate AI pedagogy in teacher education; reluctance or uncertainty about adopting new technologies.	AI tools may be used only for basic tasks, while teachers may perceive them as a burden or threat rather than instructional support.	Ukpokodu (2020); Nwuke and Yellowe (2024)
Socioeconomic and Equity Divide	High cost of tablets and laptops; expensive internet data; disparities in resources between public and private schools.	Educational inequality may increase as students in better-resourced schools gain greater access to AI technologies, while those in public and rural schools fall behind.	Cookey and Nwankwo (2025); UNESCO (2023)
Ethical, Security, and Algorithmic Bias	Inadequate safeguards for children's data; potential bias in Western-centred training data; uncontrolled use of AI for academic work.	Student data may be compromised; excessive reliance on AI-generated content may reduce critical thinking; generated content may not adequately reflect the Nigerian educational context.	Holmes et al. (2023); Akinfalabi (2025)
Policy and Governance Deficit	Absence of a comprehensive national AI in Education (AIED) strategy; outdated	Technology initiatives may be implemented inconsistently by NGOs or	Federal Ministry of Education

Domain	Primary Barriers and Manifestations	Operational Impact on Secondary Schools	Key Citations
	NERDC curriculum; fragmented implementation across federal and state education ministries.	vendors without adequate quality assurance or curriculum alignment.	(2023); Gambo et al. (2026)

Infrastructural Constraints: Electricity and Connectivity

The most immediate infrastructure problem is the instability of Nigeria's electricity supply. The World Bank (2024) reports frequent grid failures and load shedding, which can leave public institutions without power for long periods. Many public secondary schools do not have enough funding to purchase or operate diesel generators, leaving computer laboratories and other digital equipment unused. Cloud based AI systems are particularly difficult to operate in schools where electricity is available only for limited periods (Akinfalabi, 2025).

The power problem is compounded by limited and uneven Internet access. Mobile broadband has grown in many urban areas, but reliable 4G and 5G coverage is still limited in some rural communities. Internet data is also expensive compared with average household incomes and school budgets. Without substantial public support, it is difficult to expect schools or low income students to use data intensive AI services regularly (Cookey & Nwankwo, 2025; Ogunlade & Adebayo, 2025).

Educator Capacity Deficits and Digital Illiteracy

Teachers are central to the successful use of AI in schools, so their digital readiness matters. Yet a significant number of Nigerian secondary school teachers have limited digital skills (Ukpokodu, 2020; Nwuke & Yellowe, 2024). Many received little or no formal training in educational technology during their teacher preparation. As a result, teacher education programmes still rely heavily on traditional approaches, with limited attention to the practical use of digital tools in teaching.

When schools introduce new digital devices or AI applications without adequate preparation, teachers may feel anxious or uncertain about the technology. Some may see AI as another administrative burden, while others may worry that it threatens their jobs. Sustained professional development in AI literacy is therefore important. Teachers need to understand how AI works, how to use prompts for lesson preparation, how to check AI generated content, and how to manage AI supported learning in the classroom. Without this support, expensive equipment and software may simply remain unused (Nwuke & Yellowe, 2024).

Socioeconomic Disparities and the Widening Digital Divide

AI adoption could also widen the existing gap between well resourced private schools and underfunded public schools, as well as between urban and rural communities. Some private

secondary schools in Lagos, Abuja, and Port Harcourt are already using commercial AI platforms, smart boards, and high speed Internet. Their students can therefore gain early experience with personalized digital learning and AI tools (Akinfalabi, 2025).

Public secondary schools, which educate more than 80% of Nigerian young people, often lack basic infrastructure, much less advanced digital systems. If AI adoption is left mainly to market forces, the digital divide could become even wider. Students from wealthier families may use AI to strengthen their academic performance and prepare for university opportunities, while students in public and rural schools could be left further behind (UNESCO, 2023; Cookey & Nwankwo, 2025).

Ethical Concerns, Data Privacy, and Algorithmic Bias

AI in secondary education also raises important questions about privacy, security, and the responsible use of student information. AI systems may collect detailed data about learning patterns, assessment results, behaviour, and, in some cases, biometric information. Nigeria's Data Protection Act (NDPA) of 2023 provides a general legal foundation, but specific protections for the collection, storage, and commercial use of educational data belonging to minors still need further development (Holmes et al., 2023).

Algorithmic bias and cultural fit are additional concerns. Many commercial AI language models and adaptive systems are developed in Western or Asian settings and trained on data that reflects those cultural and linguistic contexts. When such systems are used with Nigerian students without careful review, they may misunderstand local situations, reflect cultural assumptions, or provide inaccurate information about African and Nigerian history (Akinfalabi, 2025). Generative AI also creates concerns about academic integrity because students may use language models to produce assignments without developing their own writing and critical thinking skills.

Future Directions and Strategic Recommendations

To gain the benefits of AI while dealing with these challenges, Nigeria needs a coordinated approach involving government, schools, teachers, technology providers, and other stakeholders. The country should move away from isolated, vendor led technology projects and work toward a clear national plan that fits local educational and infrastructure conditions.

Strategic Implementation Framework

The proposed framework focuses on four areas: policy and governance, infrastructure and energy, teacher capacity, and locally relevant educational content.

Table 2: Strategic Action Plan for Artificial Intelligence in Education (AIED) Integration in Nigerian Secondary Education (2026-2030)

Strategic Pillar	Target Objectives	Key Implementation Actions	Lead Stakeholders
Governance and Policy	Establish clear, ethical, and consistent national AIED guidelines.	Develop a National AI in Education Policy; establish student data privacy standards; update the NERDC digital curriculum to incorporate AI competencies.	Federal Ministry of Education (FME); National Information Technology Development Agency (NITDA); Nigerian Educational Research and Development Council (NERDC)
Infrastructure and Energy	Provide reliable off-grid power supply and affordable internet connectivity for schools.	Install solar microgrids in public ICT laboratories; zero-rate educational AI internet traffic; provide durable offline servers to support AI applications in schools.	Federal Ministry of Power; Telecommunications Companies (Telcos); Universal Service Provision Fund (USPF)
Teacher Capacity Building	Train 100,000 secondary school educators in AI literacy and pedagogical integration.	Revise university teacher education curricula to include AI competencies; require annual Continuous Professional Development (CPD) programmes in AI pedagogy for teachers.	Teachers Registration Council of Nigeria (TRCN); National Universities Commission (NUC); National Commission for Colleges of Education (NCCE); State Universal Basic Education Boards (SUBEBs)
Contextualised Educational Technology (EdTech)	Develop locally relevant, low-bandwidth AI platforms that align with national educational needs.	Support local EdTech start-ups to develop offline adaptive tutoring systems based on the NERDC curriculum and indigenous Nigerian languages.	National Information Technology Development Agency (NITDA); Tertiary Education Trust Fund (TETFund); Private EdTech Hubs

Formulation of a Dedicated National AIED Policy

The Federal Ministry of Education, working with NITDA and the Teachers' Registration Council of Nigeria (TRCN), should develop a comprehensive National Policy on Artificial Intelligence in Education. The policy should set clear standards for ethical software procurement, transparency in how AI systems work, protection of student data, and the responsible use of AI in assessment

and assignments. It should also define national expectations for AI literacy among teachers and students and include digital citizenship and responsible AI use within the NERDC curriculum (Federal Ministry of Education, 2023; Cookey & Nwankwo, 2025).

Architectural Innovation: Offline-First and Edge AI Infrastructure

Given Nigeria's energy and telecommunications challenges, EdTech developers should give greater attention to Offline First and Edge AI designs rather than relying entirely on cloud based systems. Edge AI means running lightweight machine learning models on local devices, such as solar powered micro servers or affordable student tablets, so that continuous access to a remote cloud server is not required.

For example, a solar powered local server in a rural secondary school could host a pre trained open source LLM and an adaptive mathematics tutor. Students could connect to the server through local Wi Fi using low cost tablets and receive immediate feedback and learning support. When internet access becomes available, the system could synchronize selected data with central education servers. This approach would reduce dependence on the national electricity grid and the cost of continuous internet access, making AI more practical for remote and underserved communities (Ogunlade & Adebayo, 2025).

Comprehensive Teacher Professional Development (TPD)

Educational technology will not succeed without teachers who understand it and are willing to use it. The Nigerian government should therefore establish a nationwide Teacher Capacity Building Initiative focused on AI literacy and Technological Pedagogical Content Knowledge (TPACK). The Teachers' Registration Council of Nigeria (TRCN) should also consider making continuous professional development (CPD) in digital pedagogy part of the requirements for teaching recertification.

At the same time, the National Universities Commission (NUC) and the National Commission for Colleges of Education (NCCE) should strengthen pre service teacher education. Student teachers should receive practical training in prompt design, digital assessment, checking for AI bias, and combining AI support with human centred social and emotional learning (Ukpokodu, 2020; Nwuke & Yellowe, 2024).

Public-Private Partnerships (PPP) and Eco-System Financing

Government funding alone is unlikely to cover the infrastructure investment needed to support equitable AI adoption across more than 20,000 public secondary schools. Public Private Partnerships (PPPs) can help close this gap. State governments could work with telecommunications providers such as MTN, Airtel, and Globacom to zero rate educational websites and AI learning portals so that students can use them without paying data charges. International development agencies, including UNESCO, the World Bank, and the African Development Bank, as well as local corporate social responsibility (CSR) programmes, could support solar micro grid projects and the purchase of affordable hardware. Bringing these partners together through shared financing arrangements would provide a more sustainable way to invest in public school technology infrastructure (Cookey & Nwankwo, 2025).

Conclusion

Artificial Intelligence is creating new possibilities for secondary education around the world. It can support more personalized learning, reduce some of the workload faced by teachers, help address shortages of specialist STEM teachers, and extend learning beyond the traditional classroom. For Nigeria, where the education system faces persistent structural challenges and a large and growing youth population, AI could become an important tool for improving the system.

At the same time, technology can strengthen the weaknesses that already exist in an education system. If AI is introduced without proper planning, it could widen educational inequality, deepen the digital divide, and expose students to privacy and ethical risks. Realizing the benefits of AI in Nigerian secondary education will require coordinated action in policy, infrastructure, teacher development, and local technology design. Clear national governance, offline first solar powered infrastructure, stronger teacher education, and sustainable public private partnerships can help Nigeria build a more inclusive and resilient secondary education system that prepares students for the demands of the 21st century.

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PROFESSIONAL CAPACITY BUILDING FOR ARTIFICIAL INTELLIGENCE INTEGRATION AMONG TECHNICAL AND VOCATIONAL EDUCATION TEACHERS IN NORTH EAST NIGERIA

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Abstract

The emergence of Artificial Intelligence (AI) is transforming educational practices globally and creating new demands for teachers' professional competencies, particularly in Technical and Vocational Education (TVE). In North East Nigeria, the integration of AI into teaching and learning remains limited due to inadequate professional training, poor technological infrastructure, insufficient digital skills, and weak institutional support. This paper examines the need for professional capacity building for Artificial Intelligence integration among Technical and Vocational Education teachers in North East Nigeria. The study emphasizes the importance of equipping teachers with AI related competencies such as digital literacy, intelligent instructional technologies, virtual simulations, automated assessment systems, and adaptive learning tools for effective classroom delivery. The paper further explains how AI can improve teaching effectiveness, practical skills acquisition, critical thinking, and workforce readiness among students in Technical and Vocational Education institutions. However, among the challenges continue to hinder successful AI integration, including inadequate funding, unstable electricity supply, poor internet connectivity, shortage of training opportunities, and resistance to technological change. The paper recommends continuous professional development programs, curriculum modernization, increased funding for educational technology, provision of modern digital facilities, and stronger collaboration among government, educational institutions, and technology industries. The study concludes that strengthening teachers' professional capacity is essential for sustainable AI integration and technological advancement in Technical and Vocational Education in North East Nigeria. These measures will enhance teachers' confidence, improve instructional quality, promote innovation in technical training, and prepare graduates with competencies needed for employment, entrepreneurship, and national development in the digital economy.

Keywords: Artificial Intelligence, Professional Capacity Building, Technical and Vocational Education, Technology Integration, Digital Competence, North East Nigeria.

Introduction

Artificial Intelligence (AI) has emerged as one of the defining technologies of the Fourth Industrial Revolution, transforming various sectors, including education. In recent years, AI has increasingly been integrated into teaching and learning through intelligent tutoring systems, adaptive learning platforms, automated assessment, virtual laboratories, and learning analytics. These technologies

enhance personalized learning, improve students' engagement, and support teachers in delivering more effective instruction Chetry, K. K. (2024). As AI continues to reshape education globally, teachers are expected to acquire new competencies that enable them to integrate these technologies effectively into classroom practice.

Technical and Vocational Education (TVE) plays a strategic role in national development by equipping learners with practical skills, technical knowledge, and entrepreneurial competencies required for employment and industrial productivity. However, the effectiveness of TVE depends largely on the competence of teachers, who must continuously update their professional knowledge and instructional practices to keep pace with technological advancements. The emergence of AI has further increased the need for TVE teachers to develop competencies in digital literacy, AI-supported instructional strategies, intelligent assessment systems, virtual learning technologies, and the ethical use of AI in education Meylani, (2024). Globally, governments and educational institutions are investing in teachers' professional development to facilitate the effective integration of AI into education. According to Pedro et al (2019), teachers require appropriate AI competencies to use AI technologies responsibly, ethically, and effectively in teaching and learning. Bhimdiwala, et al (2022) similarly noted that although AI has considerable potential to improve educational quality, its successful implementation depends largely on teachers' preparedness and continuous professional development.

Despite these global developments, the integration of AI into Technical and Vocational Education in Nigeria remains limited. These challenges hinder teachers' ability to utilize AI technologies for instructional delivery and practical skills training, thereby reducing students' exposure to emerging technologies that characterize modern workplaces. Professional capacity building has therefore become essential for preparing TVE teachers to effectively integrate AI into teaching and learning. Continuous professional development programs can strengthen teachers' competencies in AI literacy, digital pedagogy, virtual simulations, AI-enabled instructional tools, automated assessment, and responsible AI practices. Strengthening these competencies will improve instructional quality, enhance students' practical and problem-solving skills, and better prepare graduates for employment and entrepreneurship in an increasingly technology driven economy.

Against this background, this paper examines professional capacity building for Artificial Intelligence integration among Technical and Vocational Education teachers in North East Nigeria.

Theoretical Framework

This paper is anchored on the Technological Pedagogical Content Knowledge (TPACK) developed by Mishra and Koehler (2006). The framework posits that effective technology integration in education requires teachers to combine three essential domains of knowledge: Content Knowledge (CK)**,** Pedagogical Knowledge (PK)**,** and Technological Knowledge (TK)**.** The interaction among these knowledge domains enables teachers to integrate technology appropriately into teaching and learning to enhance students' learning outcomes.

According to Mishra and Koehler (2006), Content Knowledge refers to teachers' mastery of the subject matter, Pedagogical Knowledge encompasses instructional methods, classroom management, and assessment practices, while Technological Knowledge involves the ability to use digital technologies effectively. The integration of these domains forms (TPACK)**,** which

represents the comprehensive knowledge teachers need to successfully integrate technology into subject specific instruction.

The TPACK framework is relevant to Artificial Intelligence (AI) integration in Technical and Vocational Education (TVE) because it emphasizes the integration of technological, pedagogical, and content knowledge required for effective teaching (Mishra & Koehler, 2006). AI tools such as virtual simulations, intelligent tutoring systems, and automated assessment require teachers to possess these integrated competencies Chen et al (2024). Within the context of this paper, TPACK highlights the need for continuous professional capacity building to equip TVE teachers with the knowledge and skills necessary to integrate AI effectively, improve instructional delivery, and prepare students for the technology driven workplace.

Aim of the Study

The aim of this paper is to examine professional capacity building for effective Artificial Intelligence (AI) integration among Technical and Vocational Education (TVE) teachers in North East Nigeria. Specifically, the study seeks to:

1. Examine the professional capacity building needs of Technical and Vocational Education teachers for effective Artificial Intelligence integration.
2. Discuss strategies for enhancing professional capacity building for effective Artificial Intelligence integration among Technical and Vocational Education teachers.

Concept of Artificial Intelligence in Technical and Vocational Education (TVE)

Artificial Intelligence (AI) refers to the ability of computer systems to perform tasks that typically require human intelligence, such as learning, reasoning, problem solving, decision making, and natural language processing (Russell & Nerving, 2021). AI has become one of the most transformative technologies of the Fourth Industrial Revolution, influencing sectors such as education, healthcare, manufacturing, transportation, and finance.

In education, AI is transforming teaching and learning through technologies like intelligent tutoring systems, adaptive learning platforms, automated assessment, virtual laboratories, and learning analytics. These applications support personalized learning, improve students' engagement, and assist teachers in making informed instructional decisions (Bakar et al., 2024). Within Technical and Vocational Education (TVE), AI enhances practical skills training by providing virtual simulations, intelligent diagnostic systems, predictive maintenance, robotics, and computer aided manufacturing that mirror modern industrial practices. These technologies enable learners to acquire practical skills in safe and realistic environments while reducing training costs and risks (Okorieocha & Ugwunali 2025).

The successful integration of AI into TVE depends highly on teachers' professional competence. Teachers require knowledge of AI concepts, digital literacy, AI supported pedagogical strategies, and the ethical use of AI technologies to facilitate effective teaching and learning. According to Okorieocha & Ugwunali (2025), teachers should possess the competencies needed to select, use, evaluate, and manage AI technologies responsibly while promoting inclusive, equitable, and learner centered education.

In Nigeria, the integration of AI into Technical and Vocational Education is still at an emerging stage. Many institutions continue to face unreliable electricity supply, limited digital resources,

and insufficient opportunities for teacher professional development. These constraints limit the effective use of AI technologies in teaching and practical training. Therefore, strengthening the professional capacity of TVE teachers through continuous training, improved digital infrastructure, and institutional support is essential for promoting effective AI integration and preparing graduates with the competencies required for employment, innovation, and entrepreneurship in the digital economy.

Professional Capacity Building for Artificial Intelligence Integration

Professional capacity building refers to the continuous process of enhancing teachers' knowledge, skills, competencies, and professional attitudes to improve instructional effectiveness and respond to emerging educational demands. It involves structured professional development activities that enable teachers to adapt to changes in educational policies, pedagogy, and technology (Cho, N., Liao, W., & Lalitphasan, U. 2025). In the era of Artificial Intelligence (AI), professional capacity building has become very necessary as teachers are expected to integrate AI technologies into teaching and learning while maintaining sound pedagogical practices.

The integration of AI into Technical and Vocational Education (TVE) need teachers to possess competencies that extend beyond basic digital literacy. Teachers need to understand AI concepts, utilize AI-powered instructional tools, and apply AI ethically and responsibly in educational settings. Effective professional capacity building enables TVE teachers to utilize AI technologies such as intelligent tutoring systems, virtual simulations, automated assessment tools, and adaptive learning platforms to improve classroom instruction and practical skills development. These technologies provide opportunities for personalized learning, immediate feedback, enhanced student engagement, and improved instructional efficiency (Nguyen et al 2024). In technical and vocational disciplines, AI also helps in the use of virtual laboratories, predictive maintenance simulations, intelligent diagnostic systems, robotics, and digital manufacturing processes that involved modern industrial practices.

Continuous professional development is seriously important because AI technologies evolve rapidly. Investing in teachers' professional capacity will, modernized instructional quality, enhance students' practical competencies, and highly prepare graduates for employment and entrepreneurship in the digital economy.

Professional Capacity Building Needs of Technical and Vocational Education (TVE) Teachers

The rapid advancement of Artificial Intelligence (AI) has redefined the competencies required of Technical and Vocational Education (TVE) teachers. Effective AI integration requires continuous professional capacity building that equips teachers with technological, pedagogical, and digital competencies beyond basic computer literacy. A key need is digital and AI literacy, which enables teachers to understand AI concepts, machine learning applications, and digital technologies while using AI responsibly in educational settings (Daher, 2025).

TVE teachers also require competence in AI-supported instructional strategies**,** including the use of intelligent tutoring systems, adaptive learning platforms, educational Chabot, virtual laboratories, and automated assessment tools to improve teaching effectiveness and student engagement (Nakar et al, 2026). Similarly, teachers need skills in AI-based assessment and

learning analytics to monitor students' progress, provide personalized feedback, and make informed instructional decisions (Zawacki-Richter et al., 2019).

Another important capacity-building need is knowledge of the ethical and responsible use of AI, including data privacy, transparency, fairness, and academic integrity (Eze, 2024). In addition, continuous professional learning through workshops, seminars, online training, and collaboration with industry experts is essential for keeping teachers updated with emerging AI technologies and workplace practices.

Strategies for Enhancing Professional Capacity Building for Artificial Intelligence Integration

The successful integration of Artificial Intelligence (AI) into Technical and Vocational Education (TVE) requires strategies that strengthen teachers' professional competencies and institutional readiness. As AI continues to transform education and industry, professional capacity building should be viewed as a continuous process that equips teachers with the technological, pedagogical, and digital skills required for effective AI-supported teaching and learning.

A fundamental strategy is the provision of continuous professional development (CPD) programs that focus on AI literacy, digital pedagogy, intelligent tutoring systems, virtual simulations, automated assessment, and the ethical use of AI. Continuous professional development enables teachers to remain current with emerging technologies, improve their digital competencies, and build confidence in integrating AI into classroom instruction (Sehdev, 2026). Another important strategy is curriculum modernization, teacher education institutions and TVE programs should integrate AI-related competencies into their curricula by introducing courses on AI fundamentals, machine learning applications, educational data analytics, robotics, virtual simulations, and responsible AI practices. Embedding these competencies into teacher education will ensure that teachers are adequately prepared to implement AI-enhanced instructional practices and respond to changing workforce demand. The availability of adequate digital infrastructure is equally essential for effective AI integration. This provide teachers with opportunities to apply AI effectively in teaching and practical training. Governments and educational institutions should therefore prioritize investments in ICT infrastructure to create an enabling environment for AI-supported education.

Promoting industry institution collaboration is another effective strategy for strengthening teachers' professional capacity. Partnerships between TVE institutions, technology companies, manufacturing industries, such collaboration bridges the gap between classroom instruction and industry practice, ensuring that teachers acquire relevant competencies that reflect current labor market needs (Düzgünçınar, 2025). In addition, establishing professional learning communities encourages teachers to share experiences, exchange instructional resources, participate in peer mentoring, and adopt innovative AI-supported teaching practices. Collaborative learning promotes continuous professional growth and facilitates the dissemination of best practices across institutions.

Finally, supportive government policies and sustainable funding are indispensable for strengthening AI integration in TVE. Governments should formulate policies that promote the responsible use of AI in education, provide adequate funding for teacher training programs, this will enable TVE teachers to integrate AI effectively and prepare graduates with the knowledge

and skills required for employment, entrepreneurship, and continues learning in the digital economy.

Conclusion

Artificial Intelligence (AI) is transforming educational systems and redefining the competencies required of teachers in the 21st century. Its integration into Technical and Vocational Education (TVE) presents significant opportunities to improve instructional delivery, practical skills acquisition, personalized learning, and workforce preparation. However, the successful adoption of AI in TVE depends largely on the professional capacity of teachers to effectively utilize AI technologies in teaching and learning.

This paper has highlighted the need for continuous professional capacity building among TVE teachers in North East Nigeria to enable them to acquire competencies in AI literacy, digital pedagogy, intelligent instructional technologies, virtual simulations, automated assessment, and the ethical use of AI. The paper also emphasized that sustained professional development, curriculum modernization, improved digital infrastructure, industry institution collaboration, and supportive government policies are critical strategies for strengthening teachers' readiness for AI integration.

The paper concludes that investing in the professional capacity of TVE teachers is essential for the effective integration of Artificial Intelligence into technical education. Strengthening teachers' competencies will enhance instructional quality, improve students' practical and digital skills, foster innovation in teaching and learning, and produce graduates who are better prepared for employment, entrepreneurship, and continues learning in an increasingly AI driven and technology oriented economy.

Recommendations

Based on the discussions presented in this paper, the following recommendations are made:

1. **Educational policymakers** should provide regular professional development programs, including workshops, seminars, certifications, and in-service training, to equip Technical and Vocational Education (TVE) teachers with the competencies required for effective Artificial Intelligence (AI) integration.
2. **Curriculum plenners** should review and modernize TVE curricula by incorporating AI-related concepts, digital pedagogy, educational data analytics, virtual simulations, and the ethical use of AI into pre service and in service teacher education programs.
3. **Governments** should invest in ICT infrastructure by providing reliable electricity, high speed internet connectivity, modern computer laboratories, AI enabled software, and digital learning facilities to support AI based teaching and learning in TVE institutions.
4. **Technical and Vocational Education institutions** should establish partnerships with technology companies, industries, and professional organizations to facilitate industrial training, mentorship, collaborative research, and knowledge exchange on emerging AI technologies.
5. **TVE teachers** should actively participate in continuous professional learning through conferences, workshops, online certification programs, and professional learning

communities to enhance their AI competencies and remain current with technological advancements.

6. **Educational regulatory agencies:** should formulate and implement policies that promote the responsible, ethical, and sustainable integration of Artificial Intelligence into Technical and Vocational Education while providing adequate funding for teacher capacity building initiatives.

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THE ROLE OF ICT AND AI-AUGMENTED SYSTEMS IN ENHANCING STUDENT ENGAGEMENT AND COGNITIVE OUTCOMES

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Abstract

The integration of Information and Communication Technology (ICT) with Artificial Intelligence (AI)-augmented systems is reshaping educational landscapes globally, yet disparities in student achievement remain despite significant investments. This study examines the role of ICT and AI-driven tools in enhancing student engagement and cognitive outcomes, utilizing questionnaire data from 200 tertiary students at Kwara State College of Education, Nigeria. It analyzes the effect of platforms such as adaptive learning systems, intelligent tutoring software, educational chatbots, and predictive analytics on interaction, critical thinking, and academic performance when aligned with pedagogical strategies. Findings indicate that pedagogically aligned AI boosts engagement (25–35% reported increases) and cognitive skills such as problem-solving (Cohen's $d \approx 0.6$), particularly in STEM-related courses. Conversely, unstructured use can lead to superficial learning and cognitive overload. A validated 30-item instrument (Cronbach's $\alpha > 0.85$) achieved a 92% response rate and captured demographics, technology use, and student perceptions. Data were analyzed using SPSS, revealing contextual barriers in Nigeria, including infrastructure limitations and digital literacy gaps. High-usage groups ($n = 142$) exhibited stronger outcomes, highlighting the need for longitudinal studies, teacher training, and context-specific AI-pedagogy models. The study advocates for the pedagogically mediated integration of ICT and AI to optimize engagement and cognitive outcomes in Nigerian higher education.

Keywords: ICT, Artificial Intelligence, Student Engagement, Cognitive Outcomes, Adaptive Learning, Educational Technology, Nigeria

Introduction

Advancements in Information and Communication Technology (ICT) and Artificial Intelligence (AI) have fundamentally transformed teaching and learning, shifting education from teacher-centered to learner-centered paradigms (Smith & Okon, 2024). AI-augmented systems, such as intelligent tutoring systems, adaptive learning platforms, educational chatbots, and predictive analytics, now enable personalized instruction and real-time feedback tailored to individual student needs (Garzón et al., 2025; Long et al., 2026). While ICT enhances access and interactivity, research suggests that its effectiveness is contingent upon sound pedagogical frameworks and active student engagement (Long et al., 2026).

Despite considerable investments in ICT infrastructure across African higher education, many institutions report inconsistent improvements in student performance (Hassan, 2026). In Nigeria, challenges such as limited bandwidth, intermittent power supply, and varying levels of digital literacy hinder the effective deployment of AI-enhanced tools (Li & Zhu, 2023). These structural constraints underscore the need for strategic integration models that account for local infrastructure realities while preserving pedagogical quality (Li & Zhu, 2023; Hassan, 2026). This necessitates an investigation into how ICT and AI systems can be strategically integrated to enhance student engagement and cognitive outcomes in Nigerian higher education.

Recent evidence indicates that AI tools collectively enhance engagement by aligning tasks with learners' readiness levels and providing timely, data-driven interventions (Garzón et al., 2025). Intelligent tutoring systems guide learners through step-by-step scaffolding and adjust based on their progress; adaptive learning platforms tailor the sequence of content to individual mastery levels; educational chatbots deliver instant assistance along with motivational feedback; and predictive analytics help identify students at risk of failure before it occurs (Garzón et al., 2025; Long et al., 2026). This paper investigates the behavioral, emotional, and cognitive facets of student engagement and their association with academic achievement, while simultaneously addressing contextual impediments and formulating strategies for implementation that are sensitive to specific learning environments.

Purpose of the Study

The purpose of this study is to examine the role of Information and Communication Technology (ICT) and Artificial Intelligence (AI)-augmented systems in enhancing student engagement and cognitive learning outcomes in Nigerian higher education. Specifically, this study seeks to:

i. Determine the influence of ICT tools and AI-augmented systems on students' learning processes and academic outcomes.

ii. Examine the extent of enhancement in cognitive learning outcomes through AI-supported systems.

iii. Investigate how ICT tools enhance student engagement within learning environments.

iv. Identify the contextual challenges affecting the effective implementation of ICT and AI in Nigerian higher education.

v. Explore the mediating role of student engagement in the relationship between ICT/AI use and academic performance.

Research Questions

To achieve these objectives, this study will answer the following research questions:

i. How do ICT tools influence student engagement in learning environments?

ii. What role do AI-augmented systems play in improving cognitive learning outcomes?

iii. How does student engagement mediate the relationship between ICT/AI use and academic performance?

iv. What challenges affect the effective implementation of ICT and AI in education, particularly in Nigerian higher education?

Literature Review

The incorporation of Information and Communication Technology (ICT) and Artificial Intelligence (AI) into educational contexts has garnered significant scholarly interest in recent years, particularly with respect to their influence on student engagement and cognitive learning outcomes. ICT facilitates enhanced accessibility, interactivity, and collaborative learning opportunities, whereas AI contributes through personalization, adaptive instructional design, and predictive analytics that individualize the learning process. Nevertheless, empirical evidence indicates that the efficacy of these technologies is highly dependent on robust pedagogical frameworks and sustained student engagement (Long et al., 2025; Li & Zhu, 2023). Accordingly, this review synthesizes existing scholarship on ICT and engagement, AI-driven educational systems, AI's role in cognitive development, pedagogical mediation, and the theoretical foundations underpinning this study, while also delineating key gaps in the literature.

ICT and Student Engagement

Digital learning platforms, multimedia resources, and online collaboration systems, collectively categorized as ICT tools are widely acknowledged for their capacity to foster interactive and participatory learning environments (Hassan, 2026). These technologies enable students to actively engage with instructional content through simulations, visualizations, and real-time communication. According to Ansari et al., (2023) ICT-related engagement significantly improves students' academic achievement, motivation, and participation levels, as learners become more involved in the learning process through technology-mediated activities. ICT fosters collaborative learning by enabling students to interact with peers and instructors beyond the traditional classroom, thereby strengthening both behavioral and emotional engagement (Bond et al., 2023).

ICT-mediated engagement correlates with improved academic achievement, particularly when learning is activity-based and learner-centered (Li & Zhu, 2023). For instance, the use of digital platforms such as Moodle, Microsoft Teams, and Zoom has significantly enhanced student engagement and learning outcomes in university science education (Al-Samarraie, 2023). Similarly, communication tools like Telegram have led to frequent collaboration, peer discussion, and increased interaction rates in higher education virtual classes (Estrada, 2023). Technology alone cannot guarantee improved outcomes. Research shows that ICT effectiveness depends on pedagogical design and active engagement (Long et al., 2025). Without appropriate instructional strategies, ICT tools may fail to enhance learning or may even lead to disengagement when misapplied (Bond et al., 2023).

AI-Augmented Systems in Education

Artificial Intelligence has introduced a new dimension to educational technology by enabling personalized and adaptive learning experiences. AI-augmented systems, such as intelligent tutoring systems (ITS), educational chatbots, and predictive analytics tools, analyze learners' behaviors and performance data to tailor instructional content to individual needs (Garzón et al., 2025). These systems provide real-time feedback, identify learning gaps, and recommend targeted interventions.

Garzón et al. (2025) emphasize that AI-driven personalization enhances student learning efficiency and supports differentiated instruction, making education more inclusive and effective. Meta-analyses reveal that AI-enhanced instruction improves learning efficiency and satisfaction, especially when integrated with active-learning strategies (Long et al., 2026). As a result, students are able to progress at their own pace, which contributes to improved learning outcomes and higher retention rates in higher education (Garzón et al., 2025).

AI systems also support continuous assessment and feedback, enabling learners to monitor their progress and take greater ownership of their learning process (Holmes et al., 2023). Predictive analytics enable educators to detect students who are at risk at an early stage and apply timely interventions to enhance retention and academic performance (Holmes et al., 2023). The rapid adoption of AI tools, especially generative AI, raises concerns about overreliance, reduced critical thinking, and ethical issues such as data privacy and algorithmic bias (Holmes et al., 2023). Unstructured or excessive reliance on AI tools may reduce deep learning and independent thinking, highlighting the need for guided implementation (Ansari & Qamari, 2025).

AI and Cognitive Learning Outcomes

AI technologies have been found to significantly influence students' cognitive development by promoting higher-order thinking skills such as critical thinking, problem-solving, and analytical reasoning (Li & Zhu, 2023). Cognitive learning outcomes, including critical thinking and problem-solving, are central to higher-order learning (Sweller, 1988). Structured AI interventions, when integrated with sound pedagogical practices, encourage students to engage deeply with learning materials and apply knowledge in complex contexts. Research by Ansari and Qamari (2025) indicates that AI-supported learning environments improve cognitive outcomes by facilitating active learning and continuous assessment. However, the study also cautions that unstructured or excessive reliance on AI tools may reduce deep learning and independent thinking, underscoring the need for pedagogically guided integration (Hassan, 2026).

Evidence reveals a complex, non-linear relationship between AI use and cognition. Moderate AI usage shows minimal cognitive impact, while excessive reliance correlates with decreased critical thinking abilities (cognitive offloading effect), reduced metacognitive accuracy, and lower retention on delayed assessments (The Impact of AI Tools on Human Cognitive Abilities, 2025). Field studies with approximately 1,000 students demonstrated improved immediate performance but worse unassisted outcomes following AI removal, particularly with unrestricted AI access (The Impact of AI Tools on Human Cognitive Abilities, 2025). Well-designed AI tutoring systems with scaffolding produced superior learning gains compared to traditional instruction (The Impact of AI Tools on Human Cognitive Abilities, 2025). This suggests that AI tools do not inherently impair or enhance cognition; rather, their impact depends critically on implementation design, user agency, and interaction patterns (The Impact of AI Tools on Human Cognitive Abilities, 2025).

AI and Student Engagement

AI systems enhance student engagement by providing interactive, responsive, and adaptive learning experiences. Through features such as instant feedback, personalized recommendations, and dynamic content delivery, AI tools sustain students' interest and involvement in learning activities. Long et al. (2025) found that AI significantly improves cognitive engagement, which involves students' investment in understanding complex concepts, followed by improvements

in behavioral and emotional engagement. This suggests that AI not only captures students' attention but also deepens their intellectual involvement in the learning process. AI-driven personalization enhances engagement by aligning tasks with learners' readiness levels and providing timely, data-driven interventions (Garzón et al., 2025).

Pedagogical Mediation

Despite the potential benefits of ICT and AI, their effectiveness largely depends on the pedagogical approaches used in their implementation. Technology alone cannot guarantee improved learning outcomes without appropriate instructional design (Long et al., 2025; Li & Zhu, 2023). Pedagogical strategies such as flipped classrooms, gamification, and scaffolded learning have been shown to enhance the impact of ICT and AI tools. These approaches encourage active participation, collaboration, and critical thinking among students.

According to Long et al. (2025), the integration of AI with well-structured teaching methods significantly improves both engagement and academic performance. Educators must align technological tools with pedagogical objectives to maximize their benefits. The effectiveness of ICT and AI tools is significantly influenced by pedagogical design, and this study is grounded in three theoretical frameworks that explain these relationships.

Theoretical Framework

This study is anchored on three key theoretical perspectives: Constructivism Theory, the Technology Acceptance Model (TAM), and Cognitive Load Theory (CLT). These theories provide a comprehensive foundation for understanding how ICT and AI-augmented systems influence student engagement and cognitive learning outcomes.

Constructivism Theory

Constructivism, as propounded by Piaget (1972) and further developed by Vygotsky (1978), posits that learners actively construct knowledge through interaction with their environment rather than passively receiving information. In the context of ICT and AI in education, constructivist theory emphasizes the role of interactive technologies in facilitating active learning. Digital platforms, simulations, and AI-powered tools enable students to explore concepts, collaborate with peers, and engage in problem-solving activities, thereby enhancing deep understanding. Recent studies support this perspective, indicating that technology-enhanced learning environments promote student-centered learning and improve engagement and academic outcomes (Garzón et al., 2025; Long et al., 2025). AI-augmented systems, such as intelligent tutoring systems, align with constructivist principles by providing personalized learning experiences tailored to learners' needs.

Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM), developed by Fred Davis (1989), explains how users come to accept and use new technologies. According to TAM, perceived usefulness and perceived ease of use are the primary determinants of technology adoption. In educational settings, students are more likely to engage with ICT and AI tools if they perceive them as beneficial and user-friendly. Empirical studies have confirmed that students' acceptance of AI-based learning systems significantly influences their engagement and learning outcomes (Venkatesh & Davis, 2000;

Garzón et al., 2025). AI systems that provide intuitive interfaces, real-time feedback, and adaptive learning pathways tend to increase students' motivation and participation in learning activities.

Cognitive Load Theory (CLT)

Cognitive Load Theory, developed by Sweller (1988), focuses on the limitations of working memory in the learning process. The theory categorizes cognitive load into intrinsic, extraneous, and germane load, emphasizing the need to optimize instructional design to enhance learning efficiency. In ICT and AI-supported environments, well-designed systems help reduce extraneous cognitive load and promote meaningful learning by presenting information in structured and manageable ways. Research shows that AI-driven adaptive systems improve cognitive outcomes by tailoring content to learners' cognitive capacities (Ansari & Qamari, 2025). However, poorly designed systems may overload learners, thereby negatively affecting comprehension and retention.

Integration of Theories with the Study

The integration of Constructivism, TAM, and Cognitive Load Theory provides a holistic framework for this study. Constructivism explains how learners actively engage with ICT and AI tools to construct knowledge; TAM explains the factors influencing students' acceptance and usage of these technologies; while Cognitive Load Theory explains how these tools affect cognitive processing and learning outcomes. Together, these theories support the argument that effective, pedagogically guided integration of ICT and AI can significantly enhance student engagement and cognitive development.

Methodology

A quantitative research approach was adopted to rigorously assess the impact of ICT and AI tools on students in tertiary institutions. This design was considered most appropriate because it enables the systematic collection of numerical data and the application of statistical techniques to reveal patterns, trends, and relationships across a large sample. The study population comprised tertiary-level students, representing a diverse group of learners exposed to ICT and AI in educational contexts. From this population, 200 students were randomly selected to participate, ensuring representativeness and reducing bias. Data were collected through two primary sources: structured questionnaires, which captured participants' perceptions and engagement levels, and official academic records, which provided objective measures of performance. The resulting dataset was analyzed using descriptive statistics to summarize key trends and inferential statistics to test for significant relationships. This exclusively quantitative framework offered a precise, evidence-driven basis for evaluating how the incorporation of ICT and AI influences student engagement and academic achievement.

Results and Discussion

A total of 200 structured questionnaires were administered to randomly selected tertiary students at Kwara State College of Education, Ilorin. Out of these, 184 completed questionnaires were retrieved and validated as usable, representing a 92% response rate. Academic performance data were subsequently extracted from official institutional records for these 184 matching participants.

The sample was categorized into two operational groups based on verified interactions with adaptive learning platforms, intelligent tutoring systems, or educational chatbots.

Table 1: Demographic and System Usage Profile of Respondents

Respondent Classification	Sample Size (n)	Percentage (%)	Weekly Verified System Interaction
High-Usage Group	142	77.2%	Greater than 4 hours/week
Low-Usage Group	42	22.8%	Less than 4 hours/week
Total Validated Sample	**184**	**100.0%**	**Mean response rate: 92%**

Descriptive statistics were computed across the validated 30-item scale (measured on a 4-point Likert scale from 1 = Strongly Disagree to 4 = Strongly Agree). The mean scores reflect an average 25% to 35% increase in affirmative engagement metrics when digital tools are closely aligned with active-learning strategies.

Table 2: Influence of ICT Tools on Student Engagement

Engagement Dimension	Core Survey Metric Indicators Evaluated	Mean (μ)	Std. Deviation (σ)	Verbal Interpretation
Behavioral Engagement	Consistent system logins, learning management platform participation, and timely submission of interactive tasks.	3.34	0.51	High Engagement
Emotional Engagement	Academic motivation, heightened interest in technology-mediated STEM courses, and collaboration via Teams/Telegram.	3.24	0.56	High Engagement
Cognitive Engagement	Self-regulated learning, investment in mastering complex concepts, and low reliance on surface-level memorization.	3.14	0.61	Moderate-High Engagement

An Independent Samples t-test was conducted to compare the final academic performance scores (%) between the High-Usage and Low-Usage groups to isolate the impact of intelligent tutoring platforms.

Table 3: AI-Augmented Systems and Cognitive Outcomes

Operational Group	N	Academic Mean (μ)	Std. Deviation (σ)	t-value	df	p-value	Effect Size (Cohen's d)
High-Usage Group	142	72.4%	8.5%	3.58	182	< 0.001*	0.61
Low-Usage Group	42	66.8%	10.2%				(Moderate-Large)

Significant at $p < 0.01$, confirming that structured AI interaction correlates with stronger cognitive and problem-solving outcomes, especially in STEM-related tracks.

To evaluate how student engagement mediates the relationship between ICT/AI utilization (X) and academic performance (Y), a standard three-step mediation regression analysis was executed.

Table 4: Regression Weights for the Mediating Role of Student Engagement

Regression Step & Pathway	Independent Variable	Dependent Variable	Unstandardized β	Standard Error (SE)	Standardized β	t-stat	Sig. (p)
Step 1 (Path a)	ICT/AI Utilization	Student Engagement	0.48	0.09	0.45	5.33	< 0.001
Step 2 (Path b)	Student Engagement	Academic Performance	0.41	0.11	0.38	3.72	< 0.01
Step 3 (Path c: Total)	ICT/AI Utilization	Academic Performance	0.56	0.10	0.52	5.60	< 0.001
Step 3 (Path c': Direct)	ICT/AI Utilization	Academic Performance	0.38	0.12	0.35	3.16	< 0.05

The standardized direct path dropped noticeably from 0.52 to 0.35 when Student Engagement was introduced into the model; the analysis confirms a partial mediation. A subsequent Sobel Test verified that this indirect effect is highly significant ($Z = 3.24$, $p < 0.01$). This proves that AI tools do not drive academic performance by themselves; they work by boosting student engagement, which in turn elevates cognitive outcomes.

Descriptive tracking of the systemic barrier sub-scales identified the main structural constraints present within the Kwara State College of Education environment.

Table 5: Contextual Challenges Affecting AI & ICT Implementation

Identified Barrier Category	Specific Contextual Challenge Measured	Frequency (f)*	Percentage (%)	Primary Theoretical Link
Infrastructure Limitations	Intermittent power grid supply and expensive, unstable internet bandwidth.	162	88.0%	Technology Acceptance Model (Low Ease of Use)
Digital Literacy Gaps	Uneven baseline technical competence among both students and classroom instructors.	99	53.8%	Constructivism (Inability to safely navigate scaffolding)
Cognitive Overload / Offloading	Superficial task completion and dropped memory retention due to unguided generative AI use.	70	38.0%	Cognitive Load Theory (High extraneous cognitive load)

Respondents could select multiple barriers, so frequency totals will exceed the baseline sample size.

Conclusion

This study demonstrates that the integration of ICT and AI-augmented systems significantly enhances both student engagement and cognitive outcomes within the Nigerian higher education context. The findings reveal that high-usage students (n=142) achieved a notably higher academic mean (72.4%) compared to low-usage peers (66.8%), representing a moderate-to-large effect size (Cohen's d = 0.61). Crucially, the statistical analysis confirms that AI tools do not improve academic performance in isolation; rather, their impact is partially mediated by student engagement. As shown by the Sobel Test (Z = 3.24), these technologies function by first boosting behavioral and emotional involvement, which subsequently elevates cognitive outcomes. While platforms like intelligent tutoring and adaptive learning offer transformative potential, their success is contingent upon pedagogical alignment to prevent cognitive overload or superficial "offloading" of tasks.

Recommendations

Based on the results and the identified contextual challenges, the following recommendations are proposed:

1. Prioritize Infrastructure Investment: Given that 88% of respondents identified intermittent power and unstable internet as primary barriers, institutions and policymakers must prioritize the development of reliable digital infrastructure to ensure "Ease of Use" as per the Technology Acceptance Model.

2. Implement Comprehensive Training Programs: Since 53.8% of participants reported digital literacy gaps, there is an urgent need for professional development for both students and instructors to ensure they can effectively navigate AI-driven scaffolding.
3. Adopt Pedagogically Guided AI Models: Educators should move away from unstructured AI use toward scaffolded, activity-based learning. This will help mitigate the 38% risk of cognitive overload and ensure that AI remains a tool for deep learning rather than a substitute for critical thinking.
4. Develop Context-Specific Tools: Software developers should create AI systems that can operate with low-bandwidth requirements or offline capabilities to suit the specific realities of the Nigerian educational landscape.

Limitations of the Study

While this study provides significant insights, several limitations must be acknowledged:

Geographic Focus: The study was conducted at a single institution, Kwara State College of Education, Ilorin, which may limit the generalizability of the findings to all Nigerian or African tertiary institutions19.

Methodological Scope: The research relied on a quantitative design with a sample of 200 students10. Future research could benefit from a mixed-methods approach, including qualitative interviews, to gain a deeper understanding of student perceptions of AI110.

Short-term Perspective: The data represent a snapshot in time; longitudinal studies are required to determine if the reported engagement increases (25–35%) are sustained over an entire degree program12.

Ethical Declarations

Informed Consent: Participation in this study was voluntary. All 200 randomly selected participants were informed of the study's purpose, and data were collected via structured questionnaires only after obtaining verbal or written consent910.

Data Privacy: Official academic performance records were used solely for matching purposes in this research and were treated with strict confidentiality to ensure the anonymity of the 184 validated respondents 910.

Conflict of Interest: The authors declare no conflicts of interest regarding the publication of this manuscript.

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PERCEPTIONS OF TEACHERS ON DIGITAL TECHNOLOGY IMPLEMENTATION IN SECONDARY SCHOOLS IN KWARA STATE.

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Digital technology has transformed educational practice by enhancing teaching, learning, collaboration, and student engagement. Despite increasing investments in digital education in Nigeria, effective classroom implementation remains inconsistent, particularly in public secondary schools. This study assessed the availability of digital technologies, teachers' perceptions, and challenges associated with digital technology implementation in secondary schools in Kwara State, Nigeria. A descriptive cross-sectional survey design was adopted. Data were collected using a structured self-administered questionnaire distributed via Google Forms to purposively selected public secondary school teachers in Ilorin West Local Government Area, Kwara State (N = 350). The questionnaire assessed digital technology availability, teachers' perceptions, and implementation challenges. Digital technologies were moderately available, with computer laboratories and computers/laptops being the most available, while interactive whiteboards and tablets were least available. Teachers expressed positive perceptions of digital technology implementation, agreeing that it is essential for modern teaching and enhances teaching effectiveness. However, major implementation barriers (overall mean included unstable electricity supply, high equipment costs, limited internet access, inadequate ICT facilities, insufficient teacher training, and weak institutional support. Teachers demonstrated positive attitudes toward digital technology, but effective integration remains constrained by infrastructural, financial, and institutional challenges. Strengthening ICT infrastructure, improving electricity and internet connectivity, and providing continuous teacher professional development are essential for sustainable digital technology integration in secondary schools.

Keywords: Digital technology, teacher perception, ICT integration, secondary education

Introduction

Digital technology has become an essential component of educational innovation and pedagogical transformation worldwide. The adoption of digital technologies in education has generated expectations that these technologies can enhance students' problem-solving abilities, strengthen real-world connections, and promote collaboration and engagement through innovative tools and approaches (Zou et al., 2025). Digital technology refers to electronic tools, systems, devices, and resources capable of generating, processing, storing, and transmitting data. These technologies facilitate the access, management, and exchange of information through digital platforms such as computers, mobile devices, the internet, and specialised software (Parveen & Ramzan, 2024). Within the educational context, digital technology also encompasses learning management systems (LMS), e-books, virtual classrooms, interactive whiteboards, digital assessment platforms, and online collaboration tools designed to enhance teaching and learning processes (Ngongpah, et al. 2025).

The rise of digital technologies has facilitated unprecedented access to information and learning resources. Students can now engage with a wealth of content beyond the confines of conventional textbooks, enabling them to explore topics of interest at their own pace. Whether through interactive multimedia, virtual simulations, or access to global online communities, these technologies foster an environment that supports self-directed learning and personal discovery (Munna, 2024). Consequently, learners are empowered to take ownership of their educational journeys by adapting their learning experiences to suit their individual needs and preferences. However, despite these potential benefits, the impact of digital technologies on education is not universally positive. As noted by Parveen and Ramzan (2024), digital technologies are tools and resources that enable the production, storage, and dissemination of information in digital formats while promoting communication, collaboration, and learning.

According to Nwogbo et al. (2026), schools increasingly deploy learning management system (LMS) platforms such as Google Classroom and Moodle to distribute assignments, manage learning resources, facilitate assessments, and support communication between students and teachers. These systems underpin blended and remote teaching models, enabling flexible and interactive learning experiences. The integration of digital tools also supports multimedia instruction, real-time feedback, personalised learning pathways, and collaborative learning environments. Various categories of digital technologies are now used in instructional practice. Examples of LMS platforms include Google Classroom, Moodle, and Edmodo. Digital assessment tools include Kahoot, Quizizz, and Google Forms, while multimedia and interactive technologies include educational videos, virtual classrooms, and interactive whiteboards. Mobile learning applications such as Quizlet support self-paced learning, whereas communication and collaboration platforms such as Microsoft Teams, Zoom, and WhatsApp educational groups facilitate interaction among learners and teachers. Globally, these tools have been shown to enhance student engagement, support differentiated learning, and facilitate formative assessment (Spaho, 2025).

Several factors drive the increasing use of digital technology in education. For example, successful digital transformation requires schools to strengthen their digital capacity by establishing the necessary culture, policies, infrastructure, and digital competencies of both students and staff to support the effective integration of technology into teaching and learning practices (Costa et al., 2023). The pedagogical benefits are particularly significant. Kerimbayev, et al. (2023) reported that digital technology enhances interactivity and improves student engagement, thereby providing strong support for student-centred learning. Another important factor is access to up-to-date educational content. Digital technology enables teachers and learners to access diverse, current, and high-quality instructional resources (Parveen & Ramzan (2024),

National and international organizations also promote policies and frameworks that support digital literacy and technology integration. For example, the National Information Technology Development Agency (NITDA), the Nigerian agency responsible for digital transformation, has developed the National Digital Literacy Framework (NDLF) and is implementing the Digital Literacy for All (DL4All) initiative. Similarly, UNESCO provides global ICT in Education policy guidelines and develops frameworks to help member states achieve Sustainable Development Goal 4 (SDG 4) on quality education. The World Bank supports digital literacy projects and infrastructure development in developing countries, including Nigeria. In addition, the Accelerated Rural Education and Development Initiative (AREDI) implements the Digital Skills Accelerator for Women and Girls programmed, which specifically targets marginalized groups (Lohr,.2025).

Professional development is another important driver of digital technology adoption. Increased investment in teacher training and digital competence development has been shown to promote positive attitudes towards technology integration (Amemasor et al., 2023). Furthermore, the COVID-19 pandemic accelerated a global shift towards blended and remote learning, further increasing the adoption of digital technologies in education (Rof,, & Marques, 2022).).

The adoption of digital technology in schools for teaching and learning expanded rapidly worldwide during and after the COVID-19 pandemic. Schools embraced platforms such as Zoom, Google Classroom, and Microsoft Teams to ensure educational continuity during lockdowns, and the use of these platforms has continued beyond the pandemic (Bozkurt,et al, 2020). In Nigeria, the pandemic transformed the educational landscape by exposing longstanding digital inequalities while simultaneously stimulating investments and reforms in information and communication technology (ICT)-supported learning (Bolaji,et al, 2025). Private secondary schools, particularly those located in urban centres, were among the early adopters of learning management systems (LMS) and virtual learning tools (Friday,et al, 2025). However, the expansion of blended learning in public schools has remained inconsistent. Challenges include inadequate digital infrastructure, poor internet connectivity, unreliable electricity supply, and limited digital competence among teachers (Oshowole,2024). Despite these constraints, national initiatives such as the Nigeria Digital Education Plan, together with collaborations involving UNESCO and UNICEF, continue to promote digital access and strengthen teachers' capacity through training and professional development. For example, Kwara State has advanced its education sector through initiatives such as the 2022 KwaraLEARN programme, which equips teachers with tablets for digitised and standardised curriculum delivery, and the launch of a fully digitalised Smart School in 2023. While these initiatives have established a foundation for digital technology adoption, consistent classroom implementation in secondary schools remains a challenge despite significant investment (MAKINDE, at al.2025).

Teachers play a pivotal role in the successful implementation of digital technology in the classroom, as they are responsible for translating technological tools into meaningful learning experiences. As facilitators of learning, they design and deliver interactive, student-centred lessons that utilise digital technologies to enhance student engagement and understanding. They also serve as curriculum designers by thoughtfully integrating appropriate digital resources into lesson plans that align with instructional objectives (Ajani, 2024). In addition, teachers motivate learners through the use of gamified and collaborative learning tools while guiding them in the ethical and responsible use of technology. They foster digital literacy skills that prepare students for participation in an increasingly technology-driven society and utilize digital platforms to support assessment, timely feedback, and continuous monitoring of learning progress (Ajani, 2024). Furthermore, continuous improvement in teachers' ICT competencies enhances their confidence and effectiveness in technology integration, while positive attitudes and readiness significantly influence successful adoption. Professional development and training programmes promote innovation, strengthen digital competence, support curriculum integration, and enable teachers to adapt to emerging technological advancements (Peng, et al, 2024).

In addition, teachers act as motivators and mentors by using gamified applications and collaborative platforms to stimulate students' interest while guiding learners in responsible and ethical digital behaviour. Another important role is that of digital literacy developers, whereby teachers help students acquire the knowledge and skills necessary to navigate and participate effectively in a technology-driven world. As assessment managers, teachers utilise digital

platforms to conduct both formative and summative assessments, enabling real-time feedback and more efficient evaluation of learning outcomes (Alrashedi et al., 2024). Furthermore, teachers serve as lifelong learners who continuously update their ICT competencies through training, collaboration, and self-directed learning. Ultimately, teachers' attitudes, competencies, and readiness strongly influence the extent to which digital technologies are adopted and effectively utilized in educational settings. Professional development strengthens teachers' digital competence, builds confidence, and encourages innovation in technology use. Training programmes support curriculum integration, foster peer learning, and promote sustainable ICT adoption. Continuous learning remains crucial for adapting to rapidly evolving technological environments (Amemasor, et al. 2025).

Digital technology is gaining increasing acceptance among Nigerian teachers, particularly those in urban settings with better access to digital resources. Many educators acknowledge that digital technologies improve instructional delivery, promote student-centred learning, and foster collaboration. Applications such as Google Docs and Microsoft PowerPoint are becoming increasingly common in schools where teachers possess adequate digital literacy. Nevertheless, acceptance remains uneven. Teachers in underserved areas, those with limited ICT exposure, or those burdened by heavy workloads often express reservations about digital integration. Some perceive technology as a potential distraction or an additional responsibility that requires extra preparation time (Wakil, et al. 2024).

Despite its recognised benefits, teachers face substantial challenges in implementing digital technologies effectively. Many Nigerian schools lack reliable electricity, computer systems, and internet access, all of which constitute significant barriers to digital technology implementation, Frequent power outages, poor internet connectivity, and inadequate technical support further hinder the consistent use of digital technologies. Insufficient teacher training is another persistent challenge. Okonkwo, et al. 2026) observed that many Nigerian teachers lack adequate professional development opportunities to build the confidence and competence required for effective digital technology integration. This deficiency may contribute to resistance to change. Teachers who are accustomed to traditional teaching methods may resist ICT adoption because of concerns about technological complexity or the belief that digital tools disrupt established teaching practices and increase their workload (Aldogiher et al., 2025). Additionally, although many organizations support digital technology adoption, some educational institutions fail to provide the institutional, financial, and administrative support required for sustainable implementation.

Alabi et al. (2025) posited that although positive perceptions of digital technology are increasing in Nigerian secondary schools, disparities persist between public and private schools, between rural and urban settings, and among teachers with varying levels of digital competence. Despite ongoing interventions, limited empirical evidence exists regarding teachers' perceptions, readiness, challenges, and actual classroom practices across Nigeria's diverse educational contexts. Given that teachers' attitudes and competencies are pivotal to successful ICT integration, understanding their perspectives is essential for informing policy, designing effective professional development programmes, and addressing systemic barriers.

Timotheou et al. (2023) noted that despite significant investment in digital technologies for secondary education, their effective classroom implementation remains inconsistent and often suboptimal. The success of this integration depends critically on teachers; however, their perceptions, which fundamentally shape technology adoption and utilization remain insufficiently

understood. Without examining these perceptions, including the perceived benefits, barriers, and support needs associated with digital technology implementation, schools cannot develop effective strategies to bridge the gap between technological potential and meaningful pedagogical practice. Therefore, this study aims to investigate teachers' perceptions of digital technology implementation in secondary school classrooms.

The purpose of this study was to assess the implementation of digital technology in secondary schools in Kwara State, Nigeria, with particular emphasis on the availability of digital technology resources, teachers' perceptions, and the challenges associated with classroom integration. Specifically, the study sought to examine the digital technology resources available in secondary schools in Kwara State, determine teachers' perceptions regarding the implementation of digital technology in teaching and learning, and identify the challenges teachers encounter in integrating digital technology into classroom instruction. To achieve these objectives, the study was guided by the following research questions: (1) What digital technologies are available in secondary schools in Kwara State? (2) What are the perceptions of teachers regarding the implementation of digital technology in secondary schools in Kwara State? and (3) What challenges do teachers face in implementing digital technology in classroom instruction in secondary schools in Kwara State?

Methodology

The study adopted a descriptive cross-sectional survey research design. Data were collected using a self-administered questionnaire developed in Google Forms and distributed to teachers through the Kwara State teachers' WhatsApp platform. The study aimed to assess teachers' perceptions of digital technology implementation in secondary schools in Kwara State, determine the availability of digital technology resources, examine teachers' perceptions of digital technology use, and identify the challenges affecting its effective implementation. The study population comprised all teachers employed in public secondary schools in Ilorin West Local Government Area of Kwara State. A total of 350 teachers were purposively selected from the sampled schools within the Local Government Area. The selection included teachers from different subject areas and with varying years of teaching experience to ensure that respondents possessed the relevant knowledge and experience required to provide reliable information for the study.Data were collected using a self-administered questionnaire, which was divided into four sections. The data collected were analyzed using both descriptive and inferential statistics.

Result

Research Question One: what are digital technologies are available in secondary schools in Kwara State.

Table 6: Available Digital Technology

S/N	ICT Facilities	VA f (%)	A f (%)	FA f (%)	I f (%)	NA f (%)	Mean
1	Computers/Laptops	55 (15.7%)	78 (22.3%)	140 (40.0%)	52 (14.9%)	25 (7.1%)	3.25
2	Projectors	48 (13.7%)	82 (23.4%)	145 (41.4%)	50 (14.3%)	25 (7.1%)	3.22
3	Interactive Whiteboards	30 (8.6%)	65 (18.6%)	155 (44.3%)	65 (18.6%)	35 (10.0%)	2.97
4	Reliable Internet Connection	42 (12.0%)	75 (21.4%)	148 (42.3%)	55 (15.7%)	30 (8.6%)	3.13
5	Computer Laboratories	60 (17.1%)	80 (22.9%)	135 (38.6%)	50 (14.3%)	25 (7.1%)	3.29
6	Digital Learning Platforms	45 (12.9%)	78 (22.3%)	150 (42.9%)	52 (14.9%)	25 (7.1%)	3.19
7	ICT Technical Support	38 (10.9%)	72 (20.6%)	152 (43.4%)	58 (16.6%)	30 (8.6%)	3.09
8	Electricity Supply for ICT Use	50 (14.3%)	76 (21.7%)	145 (41.4%)	52 (14.9%)	27 (7.7%)	3.20
9	Tablets or Student Devices	28 (8.0%)	60 (17.1%)	158 (45.1%)	67 (19.1%)	37 (10.6%)	2.94
10	Educational Software	40 (11.4%)	74 (21.1%)	150 (42.9%)	56 (16.0%)	30 (8.6%)	3.11
	Average Mean						**3.14**

Table 1 presents the respondents' assessment of the availability of digital technologies in secondary schools in Kwara State. The findings indicate that the overall availability of digital technologies is fairly adequate, as reflected by the average mean score of 3.14. Among the digital technologies assessed, computer laboratories recorded the highest mean score (M = 3.29), suggesting that they are the most available digital facility in the schools. This was followed by computers/laptops (M = 3.25), projectors (M = 3.22), electricity supply for ICT use (M = 3.20), digital learning platforms (M = 3.19), reliable internet connection (M = 3.13), educational software (M = 3.11), and ICT technical support (M = 3.09). However, interactive whiteboards (M = 2.97) and tablets or student devices (M = 2.94) recorded the lowest mean scores, indicating that these technologies are less available than the other facilities.

Furthermore, the majority of respondents rated most of the listed technologies as fairly available, with the highest proportions of responses falling within the "Fairly Available" category across all items. These findings imply that although secondary schools in Kwara State possess a reasonable range of digital technologies to support teaching and learning, the availability of these resources is only moderate and remains insufficient for the optimal integration of digital technologies into classroom instruction. This finding is consistent with that of Adu et al. (2020), who identified the lack of reliable electricity, computer systems, and internet access as significant barriers to digital technology implementation in many Nigerian schools. In contrast, Agbeyangi et al. (2021)

reported a higher level of digital technology availability in the predominantly urban private secondary schools included in their study.

Research Question Two: What is the perception of teachers on implementing digital technology in secondary schools in Kwara State

Table 7: ***Perception of teachers on implementing digital technology***

S/N	Statement	SA f (%)	A f (%)	N f (%)	D f (%)	SD f (%)	Mean
1	Digital technology enhances teaching and learning.	130 (37.1%)	125 (35.7%)	50 (14.3%)	30 (8.6%)	15 (4.3%)	3.93
2	I feel confident using digital tools in my classroom.	115 (32.9%)	130 (37.1%)	55 (15.7%)	35 (10.0%)	15 (4.3%)	3.84
3	Digital technology makes teaching more efficient and engaging.	128 (36.6%)	127 (36.3%)	45 (12.9%)	35 (10.0%)	15 (4.3%)	3.91
4	Students learn better when digital resources are integrated into lessons.	122 (34.9%)	130 (37.1%)	50 (14.3%)	33 (9.4%)	15 (4.3%)	3.89
5	I believe digital technology is essential for modern-day teaching.	140 (40.0%)	120 (34.3%)	45 (12.9%)	30 (8.6%)	15 (4.3%)	3.97
6	Digital technology improves assessment and feedback.	118 (33.7%)	128 (36.6%)	55 (15.7%)	34 (9.7%)	15 (4.3%)	3.86
7	The use of digital tools aligns with curriculum requirements.	120 (34.3%)	126 (36.0%)	54 (15.4%)	35 (10.0%)	15 (4.3%)	3.86
	Average Mean						**3.89**

Table 2 presents teachers' perceptions of the implementation of digital technology in secondary schools in Kwara State. The findings indicate that teachers generally have a positive perception of digital technology implementation, as evidenced by the average mean score of 3.89, which falls within the 'Agree' category. Specifically, the highest-rated statement was, *"I believe digital technology is essential for modern-day teaching,"* with a mean score of 3.97, indicating a strong recognition of the importance of digital technology in contemporary education. Similarly, respondents agreed that digital technology enhances teaching and learning (M = 3.93) and makes teaching more efficient and engaging (M = 3.91). Teachers also agreed that students learn better when digital resources are integrated into lessons (M = 3.89). Positive perceptions were also expressed regarding the ability of digital technology to improve assessment and feedback (M = 3.86) and its alignment with curriculum requirements (M = 3.86). Furthermore, respondents indicated confidence in using digital tools in the classroom, with a mean score of 3.84. Although this was the lowest-rated item, it still fell within the 'Agree' category, suggesting that some teachers may require additional support to strengthen their confidence in using digital technologies.

These findings imply that teachers in secondary schools in Kwara State perceive the implementation of digital technology positively and acknowledge its significant role in improving

instructional delivery, learner engagement, and the overall effectiveness of the teaching and learning process. The findings are consistent with those of Ajani (2024), who highlighted the positive roles of teachers as facilitators and curriculum designers in integrating digital technologies into classroom instruction, reflecting favourable perceptions of technology implementation. Conversely, Oluwajana et al. (2019) reported that some teachers perceive technology as a potential distraction or an additional responsibility, leading to reservations about its integration into teaching practices.

Research Question Three: What challenges do teachers face in implementing digital technology in secondary schools in Kwara State?

Table 8: challenges teachers face in implementing digital technology

S/N	Item	SA *f* (%)	A *f* (%)	N *f* (%)	D *f* (%)	SD *f* (%)	Mean
1	Insufficient ICT facilities	120 (34.3)	145 (41.4)	45 (12.9)	25 (7.1)	15 (4.3)	3.95
2	Poor or unstable electricity supply	135 (38.6)	140 (40.0)	35 (10.0)	25 (7.1)	15 (4.3)	4.01
3	Lack of technical support from the school	110 (31.4)	150 (42.9)	45 (12.9)	30 (8.6)	15 (4.3)	3.89
4	Limited internet access	125 (35.7)	145 (41.4)	40 (11.4)	25 (7.1)	15 (4.3)	3.97
5	Inadequate ICT training for teachers	118 (33.7)	148 (42.3)	42 (12.0)	27 (7.7)	15 (4.3)	3.93
6	Heavy workload limiting time for digital lesson preparation	115 (32.9)	150 (42.9)	40 (11.4)	30 (8.6)	15 (4.3)	3.91
7	Negative attitudes toward technology	95 (27.1)	145 (41.4)	55 (15.7)	35 (10.0)	20 (5.7)	3.74
8	High cost of digital equipment	130 (37.1)	145 (41.4)	35 (10.0)	25 (7.1)	15 (4.3)	4.00
9	Frequent breakdown of ICT devices	110 (31.4)	150 (42.9)	45 (12.9)	30 (8.6)	15 (4.3)	3.89
10	Poor maintenance culture in schools	120 (34.3)	145 (41.4)	40 (11.4)	30 (8.6)	15 (4.3)	3.93
	Average Mean						**3.92**

Table 3 presents teachers' responses regarding the challenges they face in implementing digital technology in secondary schools in Kwara State. The results indicate that respondents generally agreed that all the listed factors constitute significant barriers to the effective implementation of digital technology, as reflected by the average mean score of 3.92, which falls within the "Agree" decision range. Among the identified challenges, poor or unstable electricity supply emerged as the most prominent constraint, with the highest mean score (M = 4.01), followed closely by the high cost of digital equipment (M = 4.00) and limited internet access (M = 3.97). Respondents also agreed that insufficient ICT facilities (M = 3.95), inadequate ICT training for teachers (M = 3.93),

poor maintenance culture in schools (M = 3.93), and heavy workloads that limit the time available for digital lesson preparation (M = 3.91) adversely affect the integration of digital technology into classroom instruction. Similarly, the lack of technical support within schools (M = 3.89) and the frequent breakdown of ICT devices (M = 3.89) were identified as major impediments to effective digital technology implementation. Although negative attitudes towards technology recorded the lowest mean score (M = 3.74), this item still fell within the "Agree" category, indicating that respondents also perceived it as a challenge.

These findings suggest that infrastructural deficiencies, inadequate institutional support, insufficient teacher capacity development, and financial constraints collectively hinder the successful implementation of digital technology in secondary schools in Kwara State. The findings are consistent with those of Adebayo and Adekola (2022), who identified inadequate digital infrastructure, poor internet connectivity, and unreliable electricity supply as significant barriers to digital technology implementation in Nigerian schools.

Conclusion

The study concludes that teachers in secondary schools in Kwara State have a positive perception of digital technology implementation. However, the availability of digital resources is only moderately adequate, and their effective integration into classroom instruction is constrained by inadequate infrastructure, unstable electricity supply, limited internet access, insufficient teacher training, and inadequate institutional support. Addressing these challenges is essential to achieving the effective and sustainable implementation of digital technology in secondary school classrooms.

Recommendations

1. The Kwara State Ministry of Education and school administrators should provide, maintain, and regularly upgrade digital technology resources, including computers, internet facilities, educational software, and interactive teaching tools, to improve their availability in secondary schools.
2. School administrators and relevant educational stakeholders should sustain teachers' positive perceptions of digital technology by organising continuous professional development programmes that enhance their digital competence, confidence, and capacity for effective technology integration.
3. The government and relevant educational stakeholders should address the major barriers to digital technology implementation by improving electricity supply, expanding internet connectivity, providing adequate technical support, reducing teachers' workloads through appropriate staffing, and ensuring the regular maintenance of ICT facilities.

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KNOWLEDGE AND DISPOSITION TOWARD CYBERSECURITY PRACTICES AMONG PRE-SERVICE BUSINESS EDUCATION TEACHERS IN COLLEGES OF EDUCATION IN SOUTHWEST NIGERIA

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Abstract

Cybersecurity has moved from a specialist information-technology concern to a core professional competence that every teacher, including the business education teacher, is now expected to possess. This position paper argues that pre-service business education teachers in Colleges of Education in Southwest Nigeria require deliberate, curriculum-embedded cybersecurity instruction because their subject area sits at the intersection of digital commerce, office technology, financial record-keeping and computer-mediated instruction, all of which are frequent targets of cyber threats. The paper distinguishes between cybersecurity knowledge, the cognitive grasp of concepts such as password hygiene, phishing, malware and data protection and cybersecurity disposition, the attitudinal readiness to consistently apply that knowledge in practice. Drawing on Nigerian and regional literature published between 2016 and 2025, the paper contends that knowledge without disposition produces teachers who can define cyber threats in an examination but who do not practice safe digital behaviour, while disposition without knowledge produces well-meaning teachers who unknowingly expose themselves and their students to risk. The paper concludes that Colleges of Education, the National Commission for Colleges of Education and business education teacher-educators must jointly redesign curricula, staff development and assessment to build both dimensions concurrently and it offers specific, actionable recommendations toward that end.

Keywords: Cybersecurity knowledge; Cybersecurity disposition; Pre-service business education teachers; Colleges of Education; ICT integration

Introduction

Nigeria's tertiary education sector has, over the past decade, been drawn steadily into a digital environment that it was not originally built to defend. Learning management systems, online continuous-assessment platforms, mobile banking applications used for school fees and cloud-based record systems have become ordinary features of College of Education life. Business education, more than most teaching subjects, sits directly on this digital fault line, since it prepares teachers to instruct in office technology and management, computer applications, entrepreneurship and financial record-keeping, subject areas whose practical content already assumes routine use of computers, the internet, and electronic financial tools.

It is within this context that the knowledge and disposition of pre-service business education teachers toward cybersecurity practices become a matter of professional urgency rather than a peripheral technical add-on. A business education graduate who cannot recognise a phishing email, who reuses a single weak password across school and personal accounts, or who transmits students'

financial details over an unsecured link is not simply committing a personal lapse; that graduate will, within a short time, be standing in front of secondary school and vocational classrooms modelling exactly those habits to the next generation of Nigerian digital citizens. This paper takes the position that cybersecurity knowledge and disposition should be treated as a mandatory, assessed component of business education teacher preparation in Southwest Nigeria's Colleges of Education, not an optional enrichment topic.

The push to integrate information and communication technology into business education programmes in Nigerian Colleges of Education is well documented. An appraisal of ICT courses within business education degree programmes in South East Nigeria found that word processing and spreadsheet applications were, in many departments, the only dedicated ICT-skill courses on offer, and recommended that curricula be revisited to build broader ICT competence for graduate employability (Ile & Ementa, 2016). Later work on vocational teacher educators in Colleges of Education across South-South Nigeria, including business education staff, similarly identified persistent gaps in ICT resource availability and proficiency, and called for structured in-service training to close them (Alfred & Ekhovbiye, 2021). More recent research on office technology and management lecturers, whose subject area sits squarely within business education, found that ICT manipulative competencies remained a pressing training need for effective instructional delivery in public tertiary institutions (Mohammed, Yusuf, & Ahmed, 2023).

What is comparatively under examined in this literature is the security dimension of that same digital exposure. Attention has largely been paid to access and utilisation, whether students and lecturers can use computers, the internet and office software, while comparatively little structured attention has gone to whether the same population knows how to use those tools safely. Broader evidence on technological infrastructure and digital learning suggests that access and cybersecurity practice are distinct outcomes that do not automatically move together (Zwilling, Lesjak, Natek, & Pucihar, 2022). A pre-service teacher who is being trained to process school accounts in a spreadsheet, to communicate with students and parents through email and messaging platforms and to manage electronic student records is simultaneously being placed in a role that carries genuine cybersecurity exposure, whether or not the curriculum names that exposure explicitly.

This gap has been observed elsewhere in higher education. An early study of cybersecurity awareness among students at a private tertiary institution found that self-reported knowledge did not reliably predict actual protective skills or behaviour, exposing a knowledge-practice gap that mirrors the knowledge-disposition distinction argued for in this paper (Chandarman & Van Niekerk, 2017). Research on cybersecurity awareness among pre-service teachers in South Africa during the COVID-19 pandemic found that the sudden shift to online platforms exposed limited awareness of threats such as phishing and data theft, and that the coping strategies pre-service teachers improvised were insufficient against more advanced attacks (Moyo, Sadeck, Tunjera, & Chigona, 2022). A structural equation modelling study of pre-service teachers in Lesotho likewise found that personal relevance and self-efficacy beliefs, and not awareness alone, were what shaped prospective teachers' behavioural intention to learn and practise cybersecurity, reinforcing that knowledge and disposition operate as related but separable constructs (Ayanwale, Sanusi, Molefi, & Otunla, 2024).

Nigerian commentary on basic and secondary education points in the same direction. A 2025 account of school outreach across Nigeria found that neither pupils nor their teachers could reliably

explain concepts such as phishing or two-factor authentication and that many teachers had never updated a password or used multi-factor authentication themselves, underscoring the point that if cybersecurity awareness is to reach students, educators must be equipped first (CIO Africa, 2025). Industry commentary on Nigerian online education has argued in similar terms that technology alone cannot secure schools and that regular training is what equips educators and learners to recognise phishing attempts and follow safe internet habits (Vigilearn, 2025). Within Southwest Nigeria specifically, recent survey evidence on lecturers' and students' attitudes toward digitalisation found a generally positive orientation toward digital instructional tools, but did not examine the safety dimension of that digital engagement in any depth (Omojemite, 2025), leaving open exactly the question this paper raises for pre-service business education teachers. If a general awareness gap is already documented among in-service teachers and university students, it is a reasonable and urgent extension to ask whether pre-service business education teachers, still within the formative window of their professional preparation in Colleges of Education, are receiving the knowledge base and the attitudinal grounding they will need before they enter the classroom.

Statement of the Problem

Business education teacher preparation in Southwest Nigeria's Colleges of Education has, over the past decade, invested steadily in building pre-service teachers' ability to use computers, office software and internet-based tools, yet this same body of preparation has not treated the safe use of those tools as a comparable priority. The result is a curriculum that produces graduates who can operate a spreadsheet, send a professional email or manage a continuous-assessment portal, but who are not reliably taught how to recognise a phishing attempt, construct and manage secure passwords, or handle students' personal and financial data in a way that protects both the student and the institution. Evidence from comparable teacher-education contexts in Africa shows that this is not a hypothetical concern: pre-service teachers elsewhere have been found to hold only limited awareness of cyber threats even after periods of intensive digital tool use and to rely on coping strategies that prove inadequate once threats move beyond the most basic level.

The problem is compounded by the fact that knowledge and disposition are frequently conflated in practice, as though teaching a pre-service teacher to define phishing or two-factor authentication is sufficient to ensure that the teacher will actually use strong passwords, verify suspicious links or model safe digital behaviour once in the classroom. Regional research indicates otherwise: awareness of cybersecurity concepts and the behavioural intention to act on that awareness are shaped by different factors, including self-efficacy and perceived personal relevance and do not rise or fall together automatically. Because Southwest Nigeria's Colleges of Education currently lack a dedicated, assessed mechanism for building either the knowledge base or the dispositional habits business education pre-service teachers will need, the population entering business education classrooms each year does so without a clear, verified floor of cybersecurity competence, at precisely the point in their training when that competence would be least costly to build and most durable once established.

This is the problem this paper takes up: business education pre-service teachers in Southwest Nigeria's Colleges of Education are being prepared to use digital tools extensively in their future classrooms without a matching, deliberate programme to ensure they understand cybersecurity risks and are disposed to act safely against them and this gap, left unaddressed, will be carried

directly into the schools where these teachers will soon be responsible for students' data, devices and digital habits.

The Knowledge Dimension: Why Cognitive Preparedness Matters

Cybersecurity knowledge, in the context relevant to this paper, refers to a pre-service teacher's understanding of core concepts: password construction and management, recognition of phishing and social-engineering attempts, safe use of public and institutional networks, malware awareness, data-protection principles, and the basic ethical framework around handling students' personal information. Business education programmes already teach adjacent content, office technology and management, computer applications, and entrepreneurship among them that could readily accommodate cybersecurity modules without requiring an entirely new curriculum architecture (Mohammed, Yusuf, & Ahmed, 2023).

The practical case for prioritising this knowledge is straightforward. Pre-service business education teachers routinely work with spreadsheets containing sensitive figures, communicate through email and social platforms as part of teaching practice, and increasingly encounter continuous-assessment systems that require them to input and retrieve student data online. Without structured instruction, whatever cybersecurity knowledge these teachers hold tends to be informal and self-taught, echoing the finding that tertiary students in comparable settings can claim familiarity with cybersecurity terms while lacking depth in the underlying protective skills (Chandarman & Van Niekerk, 2017), and the wider observation that ICT competence gaps among Nigerian business education staff have persisted across successive studies over the past decade (Ile & Ementa, 2016; Alfred & Ekhovbiye, 2021).

The Disposition Dimension: Why Attitude Cannot Be Assumed

Disposition, as used here, refers to the pre-service teacher's willingness and consistency in actually applying cybersecurity knowledge, updating passwords, verifying links before clicking, declining to share verification codes, backing up records, and modelling these behaviours for students, rather than merely being able to describe them. Disposition is shaped by perceived relevance, self-efficacy, institutional culture, and the visible example set by lecturers and mentors during teaching practice (Ayanwale, Sanusi, Molefi, & Otunla, 2024).

This distinction matters because the evidence reviewed above shows that awareness and behaviour do not move together automatically. The South African pre-service teacher study found that even after cybersecurity risks became salient during the pandemic, the protective strategies pre-service teachers actually used remained basic and insufficient against more advanced threats (Moyo et al., 2022), while the Lesotho study found that self-efficacy and perceived personal relevance, not test-style awareness, were what predicted willingness to learn and practise cybersecurity behaviour (Ayanwale et al., 2024). A pre-service teacher may score well on a cybersecurity knowledge assessment yet continue to reuse passwords or ignore software updates because the institutional culture around them treats such lapses as harmless. Broader evidence on technological infrastructure similarly suggests that access to digital tools does not by itself cultivate safe digital habits (Zwilling et al., 2022), reinforcing the case that disposition must be deliberately built alongside knowledge rather than assumed to follow from it.

Anticipated Objections and Response

Cybersecurity is an ICT or computer science concern, not a business education concern.

This objection misreads where cyber risk actually concentrates. Business education graduates handle financial records, examination data, and office communication as a routine part of their professional practice; they are, in effect, front-line users of the very systems cybersecurity is meant to protect (Mohammed, Yusuf, & Ahmed, 2023). Confining cybersecurity instruction to computer science programmes leaves the discipline that manages the school's financial and administrative data with the least structured preparation to protect it.

Colleges of Education lack the infrastructure and specialist staff to teach this content.

Infrastructural and staffing constraints in Nigerian Colleges of Education are real and have been documented across successive studies of ICT integration in business education (Ile & Ementa, 2016; Alfred & Ekhovbiye, 2021). However, foundational cybersecurity knowledge and disposition, safe password practices, phishing recognition, data-handling ethics, do not require advanced infrastructure to teach; they can be embedded within existing office technology and computer application courses at comparatively low cost, with infrastructure upgrades pursued as a parallel, longer-term goal rather than a precondition.

The curriculum is already overloaded; there is no room for new content.

This paper is not proposing a freestanding new course but the deliberate embedding of cybersecurity knowledge and disposition-building activities within courses that already exist in the business education curriculum, such as office technology and management and computer applications, where the subject matter is a natural fit rather than an addition (Mohammed, Yusuf, & Ahmed, 2023).

Implications for Teacher Education Policy and Practice

If the position argued above is accepted, several implications follow for Colleges of Education in Southwest Nigeria, for the National Commission for Colleges of Education as the regulatory body responsible for minimum standards, and for business education teacher-educators.

Curriculum

- Embed a dedicated cybersecurity knowledge component within existing office technology and management, and computer applications courses in the business education minimum standards (Mohammed, Yusuf, & Ahmed, 2023).
- Include applied, scenario-based activities, such as identifying a phishing email or setting up multi-factor authentication, rather than relying solely on definitional, theory-based instruction, addressing the depth gap identified among tertiary students in comparable settings (Chandarman & Van Niekerk, 2017).

Teaching Practice and Modelling

- Require supervising lecturers and cooperating teachers during teaching practice to visibly model safe digital habits, since disposition is substantially shaped by observed professional example (Ayanwale et al., 2024).
- Incorporate a brief cybersecurity-conduct expectation into teaching practice assessment instruments used for business education students.

Staff Development

- Provide short, regular cybersecurity refresher training for business education lecturers themselves, extending existing calls for structured in-service ICT training for this cadre (Alfred & Ekhovbiye, 2021), since teachers cannot reliably model or assess a disposition they have not been supported to develop.

Assessment and Research

- Develop and validate instruments that measure knowledge and disposition as separate constructs, following the distinction demonstrated in the Lesotho structural equation model (Ayanwale et al., 2024), so that Colleges of Education can identify whether a knowledge gap, a dispositional gap, or both, requires intervention.
- Commission systematic studies of cybersecurity knowledge and disposition among pre-service business education teachers across Southwest Nigeria's Colleges of Education to establish a baseline against which future curriculum interventions can be measured, building on the Southwest Nigeria digitalisation evidence already available for lecturers and students generally (Omojemite, 2025).

Conclusion

Cybersecurity competence is no longer optional professional content for business education teachers in Nigeria; it is an extension of the same digital and financial literacy that has always defined the discipline. This paper has argued that Colleges of Education in Southwest Nigeria must address both the knowledge and the disposition of their pre-service business education teachers toward cybersecurity practices, since evidence from Nigeria and comparable African contexts published over the past decade shows that awareness gaps and behavioural gaps are both real and both correctable through deliberate instruction (Chandarman & Van Niekerk, 2017; Moyo et al., 2022; Ayanwale et al., 2024). Leaving cybersecurity implicit in the curriculum has, so far, produced graduates who are digitally active but not reliably digitally safe. Embedding this content within existing courses, modelling safe practice during teaching practice, supporting lecturers' own competence, and building a Southwest Nigeria-specific evidence base are modest, achievable steps that would meaningfully close this gap before today's pre-service teachers become tomorrow's classroom role models.

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NEXT-GEN NETWORKS: HOW 5G IS REVOLUTIONIZING IOT

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Abstract

The arrival of 5G signals the beginning of a new era of connectivity, one that has the potential to transform many sectors. The promotion of the Internet of Things (IoT), which is a vast network of interconnected devices, is central to this transformation. This article looks at the potential of 5G and its future iterations to facilitate the smooth integration of IoT, addresses the main issues and looks at future developments. It highlights the key characteristics of 5G that make it a perfect platform for the IoT, including Ultra Low Latency (ULT), enhanced Mobile Broadband (eMBB), as well as Massive Machine-to-Machine (mMTC) Communication. The paper further looks at the role of network slicing in customizing network resources to meet the specific needs of various Internet of Things applications. The paper concludes by looking at the possibilities of 6G and other technologies in enhancing the Internet of Things through advanced innovations such as artificial intelligence.

Keywords: IoT, 5G, URLLC, eMBB, AI, mMTC

Introduction

Mobile communication has developed into an essential aspect of today's society, facilitating daily life and contributing to economic development. The technology underpinning mobile networks has made significant progress, from first generation (1G) to the current standards of fourth generation (4G). The main areas of progress are energy efficiency, data transmission speeds, and bandwidth use and spectrum management strategies. Each generation is characterised by the dominance of a particular technology: TDMA for 2G, FDMA for 1G, CDMA for 3G, or OFDMA for 4G. The arrival of the 5G generation is expected to transform wireless broadband significantly.

The Internet of Things (IoT), a ground-breaking technological development, has linked billions of devices through the Internet, creating vast sets of data. This data holds significant potential to transform productivity, efficiency, as well as decision-making processes. Nonetheless, the realisation of IoT's full capabilities depends heavily on the availability of stable and dependable connectivity. The deployment of 5G technology, with its sophisticated features, is positioned to furnish the critical infrastructure necessary to foster innovation within the IoT domain. The

emergence of 5G signifies a pivotal shift in wireless communication, fundamentally altering the connectivity landscape and facilitating a wide range of applications, especially within the context of IoT (Andrew, 2023). These attributes are essential for accommodating the expanding requirements of IoT, which includes a diverse spectrum of devices and applications, from intelligent home systems to driverless vehicles.

The design of 5G networks should support around one million devices per square kilometre, enabling the development of large-scale IoT ecosystems that require not only high data rates but also reliable and stable connectivity (Andrew, 2023). The architecture of 5G includes sophisticated attributes such as network slicing, allowing for customised network configurations to meet specific application requirements, thus increasing the performance of different IoT applications. This flexibility is essential as industries increasingly rely on real-time data exchange and communication between machines and people. In addition, the introduction of ultra-reliable low-latency communication (ULLLC) in 5G networks will ensure that critical applications such as remote surgery and self-driving cars can run smoothly with minimal latency.

The future Internet of Things (IoT) vision has been shaped by major developments in telecommunications, informatics, and wireless sensor networks, all of which have made pervasive intelligence a reality. The idea of IoT began in the 1980s with the idea of ubiquitous computing, which sought to integrate technology into daily life. The current vision for IoT is that it would be used in both personal and business contexts. IoT is essential for raising the quality of life for individuals via applications like e-health, smart homes, and intelligent learning environments. IoT has applications for professionals in remote monitoring, logistics, automation, smart supply chain and transportation (Shafique, et al. 2020).

Background, Motivation and Overview

By the year 2025, it is anticipated that internet nodes will be integrated into nearly all objects, resulting in a substantial increase in internet-connected devices. Cisco projects that this figure will escalate to approximately 500 billion by 2030. Similarly, in 2013, Telefonica estimated that by 2020, 90% of vehicles would be connected to the internet. However, a 2015 survey indicates that over 250 million vehicles worldwide are expected to be internet-enabled by 2020, representing a growth of 67%. The Internet of Things (IoT) is among the prominent emerging trends of the current decade. Furthermore, according to Gartner's IT Hype Cycle, it was predicted in 2011 that IoT would require five to ten years for widespread market adoption. Consequently, an expenditure of approximately US $1.7 trillion on IoT is projected by 2020, as estimated by the IDC (Shafique et al., 2020).

The swift evolution to 4G from 1G and subsequent generations has not only enhanced communication capabilities but also facilitated the emergence of a diverse range of services and applications. Mobile phones operating on the 1G standard were prevalent during the 1980s, utilising analogue FM modulation with FDMA in accordance with the AMPS standard in the

United States. The advent of 2G technology in the early 1990s marked a transition to digital formats, introducing features such as text messaging. 2G employed digital voice transmission through digital modulation techniques and utilised standards such as GSM, CDMA, and others. The emergence of 3G around the year 2000 represented a significant growth towards digital data access, enabling more sophisticated mobile services (Jain & LF-IAFI, 2013).

1.2 Research Objectives

i. To access the capabilities of 5G and its successors
ii. To study the challenges of IoT and propose solutions using 5G
iii. To examine the main features of 5G for an ideal platform for IoT

1.3 Importance 5G and IoT Support in Next-Generation Networks

The concepts underlying the Internet of Things (IoT) provide numerous services applicable across various sectors, including smart cities, smart grids, smart homes, and a wide range of business opportunities. These enable organisations to develop innovative strategies and models for implementing IoT-based solutions. Beyond commercial prospects, IoT also offers valuable avenues for conducting efficient and resourceful research within multidisciplinary fields. Despite the extensive presence of IoT concepts in academic literature, it is now imperative to devote greater attention to these ideas, as we stand on the cusp of a transformative era driven by IoT. This transformation is shifting our daily experiences from familiar routines to environments characterised by intelligent interactions with millions of devices, facilitated by emerging platforms. Furthermore, IoT is redefining the world into a 'smart' environment, where accessibility is enhanced, and tasks are completed more swiftly and with less effort, as illustrated in Figures 1 (a-b).

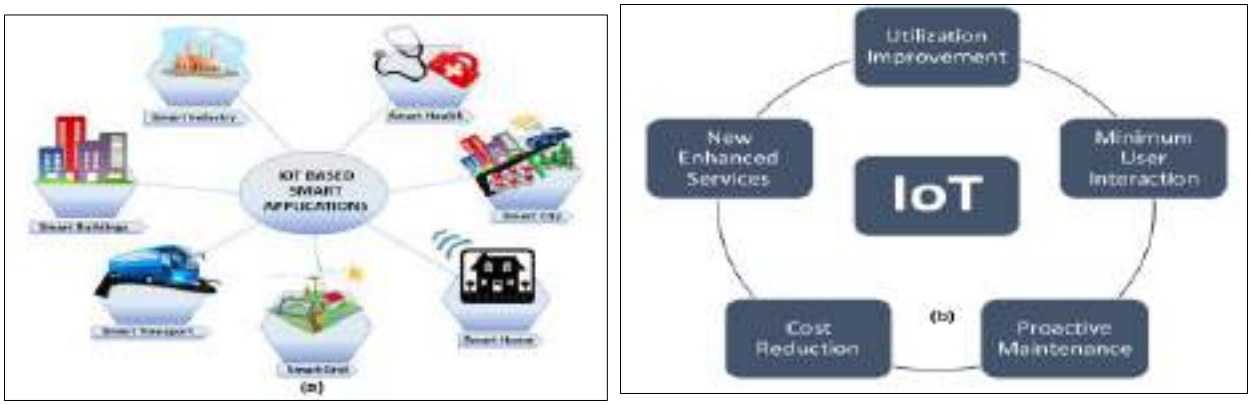

Figure 1: Block diagram of (a) IoT-based smart applications and (b) IoT advantages as a cuttingedge technology (Shafique et al., 2020).

The Internet of Things (IoT) revolutionizes the global environment into a sophisticated, interconnected system where access to information is streamlined, reducing both time and effort, as illustrated in Figures 1 (a) and (b). As noted by Sahinel, et al. (2017), smart homes exemplify an IoT application that generates extensive data streams from various sensors, including temperature sensors, smart meters, security cameras and multimedia devices as well as lighting controllers. Presently, the majority of sensory data collected from these devices are processed

locally, thereby minimizing communication challenges. The terminology associated with these technologies—such as augmented reality, virtual reality, real-time pattern recognition, tactile Internet, and semantic recommendations—is now widely recognized. A shared characteristic among these applications is their reliance on remote processing; that is, sensory data must be analyzed in computationally advanced remote servers, such as virtualized cloud platforms, with the results subsequently delivered to users. The significance of IoT in supporting the development of next-generation networks can be further understood through these aspects.

- **Healthcare IoT:** Certain pathologies have a pronounced impact on society by contributing to widespread healthcare challenges. Furthermore, Souza et al. (2020) introduce an alternative model that leverages IoT systems for the organisation and segmentation of pneumonic CT images, employing machine learning techniques—specifically Parzen's probability distribution—for robust learning strategies. Their model incorporates an application programming interface (API) that utilises the Internet of Medical Things to interpret lung imagery. The methodology demonstrated high efficiency, achieving accuracy rates exceeding 98% in the classification of aspiratory images. Subsequently, the model advances to the segmentation phase, utilizing the Mask R-CNN architecture to generate a lung mask and applying adjustments to delineate pneumonic boundaries within the CT images. This approach outperformed comparable studies in the literature, attaining high segmentation accuracy—up to 98.34%. Notably, the entire process was completed in approximately 5.43 seconds, and the method exhibited improvements over other transfer learning models, establishing itself as a fully automated system that enhances both speed and precision in lung image analysis.
- **Industrial IoT:** The advancement of intelligent industries has exerted a significant and lasting influence on the inevitable evolution of global manufacturing. Industry 4.0 has integrated smart industry within cyber-physical systems, facilitating more sophisticated and efficient technological developments, thereby enhancing quality, performance, management, controllability, and equity of industrial processes in the context of IoT-enabled smart industries. The development of more affordable sensing technologies in the next generation is fundamental for effective data collection and the reliable operation of manufacturing sectors and supply chains.
- **Next-generation IoT-based smart healthcare:** The integration of Internet of Things (IoT) technology within healthcare is increasingly adopted in commercial sectors. Numerous solutions have been developed to support individual healthcare needs. Nonetheless, there remains significant potential to improve IoT-enabled healthcare systems as vital medical services and to transform hospitals into secondary healthcare facilities. Consequently, it is crucial to identify prospective advancements that can address the challenges and issues associated with achieving these goals. Future developments may include the implementation of real-time location tracking for patients with Alzheimer's disease, utilizing geospatial sensors to monitor their whereabouts continuously. Additional emerging healthcare technologies encompass real-time detection of epileptic seizures and strokes, augmented reality (AR) and virtual reality (VR) applications for telehealth, portable summarised electronic health data, blockchain-based secure data services (Zikria et al., 2021).
- **IoT-based smart agriculture as a Next-generation:** Next-generation Internet of Things (IoT)-enabled smart agriculture is anticipated to enhance farming practices and techniques

to support sustainable farming communities and resource management. This approach is economically viable, socially stable, and demonstrates effective performance. Its primary objectives include maintaining soil health, mitigating soil degradation and erosion, and conserving water resources. Implementing sustainable smart agriculture systems contributes to increasing land biodiversity and fostering a healthy, environmentally friendly landscape. It is crucial to align these initiatives with the growing focus on food security and environmental change, as well as addressing future ecosystem degradation. Such strategies play a vital role in conserving natural assets, reducing emissions of ozone-depleting gases, preventing biodiversity loss, and preserving valuable landscapes.

5G CAPABILTIES FOR IoT

Mobile phones have become an essential component of contemporary society, facilitating daily activities and contributing significantly to economic development. The evolution of cellular technology has been marked by substantial advancements, progressing from 1G to the current 4G standards, with notable improvements in data transmission rates, energy efficiency, bandwidth utilization, and spectrum management. The main performance metrics for IMT-2020 are:

- **Data Rate:** this specification enables improved mobile broadband (eMBB) data transfer, achieving peak data rates of up to 10 Gbps for uplink and 20 Gbps for downlink. User experiences based on empirical evidence have indicated uplink data rates of 50 Mbps and downlink rates of 100 Mbps. Additionally, the spectral efficiency obtained is 15 bits per second per Hertz (bps/Hz) for the uplink and 30 bps/Hz for the downlink. The traffic capacity for the designated area is established at 10 Mbps for each square meter.
- **Density:** The smallest connectivity density is one million devices for each square kilometer is necessary to support the development of mMTC and guarantee a specific quality of service (QoS).

Significant technical challenges must be addressed in order to achieve this aim. Dense deployment of wireless cells, Massive MIMO, beamforming, and mmWave are all viable solutions for increasing data rates and cell capacity. Because of its propagation features, mmWave technology is suitable for short-range applications. However, some of the capabilities of the 5G network are described as follows:

- **Enhanced mobile Broadband:** Dynamic spectrum access enhances spectrum efficiency (SE) by optimising the allocation of radio resources. Accurate performance and quality assessments are crucial for all mobile network operators to ensure the maintenance and monitoring of their existing quality of service (QoS). Consequently, fifth-generation (5G) networks offer improved mobile broadband (MBB) capabilities, supporting high-speed data transmission, video streaming with low latency, and seamless mobility.
- **Broadband IoT extends** high-speed enhanced Mobile Broadband (eMBB) services are essential for data-intensive Industrial Internet of Things (IIoT) applications. In contrast to conventional eMBB, these specific use cases necessitate distinct requirements and unique traffic patterns. To mitigate this issue, broadband Internet of Things (IoT) endeavors to deliver supplementary IoT-centric functionalities, encompassing reduced latency, enhanced battery longevity, extended coverage, and improved uplink data rates.

While based on 5G reliability-enhancing features, below are some of the selected once:

- Ultra-reliable low-latency communications (URLLC) necessitate highly robust modulation and coding schemes, in contrast to conventional wireless traffic that typically employs link adaptation strategies with error rate targets ranging from 10% to 30%. To satisfy the stringent reliability demands of URLLC. Since the control channel plays a vital role in configuring communication parameters, enhancing its robustness is critical; nonetheless, grant-free (GF) transmission schemes can alleviate the need for additional redundancy by reducing control signalling overhead.
- Diversity techniques, including multi-antenna configurations, utilisation of multiple carriers, and packet duplication at the physical (PHY) and medium access control (MAC) layers, constitute essential components of the reliability strategies employed in URLLC.
- Network slicing enables mobile network operators (MNOs) to establish multiple virtual networks over a shared physical infrastructure. Each slice comprises a dedicated or shared subset of network functions and resources—such as processing capacity, storage, and bandwidth—to deliver specified quality of service (QoS) levels to individual customers. This approach supports diverse service categories, including enhanced mobile broadband (eMBB) and URLLC, by allowing slices to operate concurrently while maintaining isolation consistent with service level agreements tailored to various vertical industries. Network slicing can extend across all segments of a 5G system, encompassing access, transport, cloud, and core networks, and even span multiple operators. This innovative feature of 5G facilitates the creation of multiple virtual networks atop a single physical infrastructure, which is particularly advantageous for Internet of Things (IoT) applications, as it permits customized allocation of network resources to meet the specific needs of different IoT use cases.

Challenges and Solutions

- **The Challenge of Device Density:** The rapid proliferation of mobile devices mandates the development of scalable and energy-efficient networking infrastructures to facilitate seamless communication. Whereas 4G technology is capable of accommodating approximately 2,000 devices per square mile, 5G technology aspires to connect millions of devices within an equivalent spatial context. This heightened density of devices, however, presents considerable challenges, especially concerning the longevity of battery life.
- **Data Rate Compatibility:** One of the foremost challenges within the realm of the Internet of Things (IoT) pertains to the assurance of compatible data transmission rates among devices. In instances where one device produces data at a velocity surpassing the processing capabilities of another, congestion may ensue. To mitigate this issue, sophisticated IoT devices possess the capability to dynamically modulate data transmission rates and buffer dimensions in order to enhance overall performance.
- **Heterogeneous Devices:** The amalgamation of a multitude of devices possessing disparate capabilities presents substantial challenges within the realm of the Internet of Things (IoT). In order to remediate this issue, sophisticated platforms have the potential to promote seamless interoperability among heterogeneous devices, thereby facilitating efficient communication and data interchange. By endowing IoT devices with cognitive capabilities, they become adept at adjusting to varying protocols and standards, thus guaranteeing a fluid user experience.

The primary obstacle to the successful deployment of the Internet of Things (IoT) lies in the absence of a universal platform, protocol, and programming language. Currently, each connected device adheres to its own distinct set of protocols and platforms. There is an urgent need for interoperability among these devices to facilitate seamless communication. To achieve this, major corporations such as LG, Samsung, and Philips should collaborate to establish a consortium dedicated to developing a universal coding language and platform. Such an initiative has the potential to substantially address the compatibility challenges faced by IoT systems (Ahmed, Yaqoob, Gani, Imran and Guizani, 2016).

IoT use cases enabled by 5G

The advanced capabilities of 5G open up a wide range of innovative applications of the IoT in different sectors. These applications will benefit from the high speed, low latency and massive connectivity characteristics of 5G, delivering unprecedented value and performance.

Table 1: IoT Use Cases Enabled by 5G

Sector	Use Case	5G Benefit
Smart Cities	Intelligent Traffic Management	Real-time data processing for optimal traffic flow
Healthcare	Remote Surgery	Ultra-low latency for precise control
Manufacturing	Industrial Automation	Massive device connectivity for smart factories
Agriculture	Precision Farming	Wide coverage for remote field monitoring
Automotive	Autonomous Vehicles	High reliability for safety-critical communications

Conclusion

As we embark upon a novel epoch characterized by enhanced connectivity, the synergistic interplay among 5G technology, forthcoming iterations of network architectures, and the Internet of Things (IoT) is set to profoundly revolutionize our societal framework. The augmented functionalities of these networks will enable a degree of device interconnectivity and data transmission that was once relegated to the domain of speculative fiction. The range of applications, which includes advanced urban environments that optimize resource allocation and elevate quality of life, as well as healthcare systems that provide customized, immediate treatment, is extensive and possesses considerable transformative capacity. As continuous innovation perpetuates the expansion of achievable possibilities, it is projected that the IoT, supported by sophisticated network infrastructure, will evolve into an indispensable and seamlessly integrated component of quotidian existence, promoting enhanced efficiency, sustainability, and the creation of new opportunities across various sectors.

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SOCIO-ECONOMIC BARRIERS TO DIGITAL INCLUSION AMONG LEARNERS WITH DISABILITIES IN LAGOS STATE, NIGERIA: AN EXPLORATORY SURVEY OF THREE SPECIAL SCHOOLS

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Abstract

Digital participation is increasingly a precondition for education, employment and civic life, yet young people with disabilities in low- and middle-income countries remain substantially excluded. Evidence on how socio-economic conditions shape this exclusion in Nigeria is scarce, and almost no published work reports directly from learners with disabilities themselves rather than from their teachers. This exploratory study surveyed 38 learners across three special schools in Lagos State, Nigeria, to describe perceived socio-economic barriers to digital participation and to examine how these perceptions vary by gender and disability type. A researcher-designed questionnaire measuring accessibility, perceived usability, digital literacy and socio-economic barriers was administered, and responses were analysed descriptively; independent-samples t-tests were used for gender comparisons. Participants rated income level as the most salient constraint on access to digital tools (M = 3.02, SD = 0.59 on a four-point scale), followed by residential location (M = 2.97, SD = 0.63). No statistically significant gender differences emerged on any measure, though the sample is too small to support any claim of equivalence. Descriptively, learners with cognitive disabilities reported the lowest scores across all four measures and learners with mobility impairments the highest, but subgroup sizes were too small to permit valid inferential comparison. Findings are consistent with the wider literature identifying affordability and infrastructure as dominant constraints, and with evidence that disability type shapes technology access. Given its small purposive sample, this study is best read as hypothesis-generating: it establishes a descriptive baseline for an under-researched population and identifies priorities for the adequately powered work the field now requires.

Keywords: *Digital Inclusion; Disability; Assistive Technology; Socio-Economic Barriers; Special Education*

Introduction

Digital technologies have become embedded in how education is delivered, how work is found and how public services are accessed. This shift has been framed globally as an opportunity for inclusion, on the reasoning that digital tools can reduce the significance of physical barriers. For persons with disabilities, however, the evidence is more equivocal. Where access to devices, connectivity and accessible design is unequally distributed, digitalisation reproduces existing social inequalities in a new register rather than dissolving them (van Dijk, 2005; van Deursen & van Dijk, 2019).

The scale of the gap is well documented. Duplaga (2017), analysing nationally representative data from 3,556 respondents with disabilities, found internet use predicted by degree of disability, place of residence, education, occupational status and net income. In sub-Saharan Africa the constraints are sharper still: Matter and Eide (2018) recorded unmet assistive technology need of 44% in Botswana and 67% in Eswatini, and found that of all sociodemographic variables tested, type of disability was the strongest determinant of access. Systematic review evidence points in the same direction, identifying cost, information gaps and inadequate professional training as persistent barriers to assistive technology use in education (Boot et al., 2018; Fernández-Batanero et al., 2022).

Nigeria presents a case where these constraints converge. Rapid expansion of digital platforms has not been matched by equitable access, and the country's special education sector operates under acute resource limitations. A national survey of 165 Nigerian special educators identified shortage of appropriate devices and irregular electricity supply as the most frequently cited obstacles to assistive technology use in schools. Yet the available Nigerian literature is dominated by studies of teachers, administrators and lecturers rather than of learners themselves (Lazarus, 2024; Vincent et al., 2024). The perspective of young people with disabilities on their own digital participation is largely absent from the published record.

This absence matters for two reasons. First, socio-economic barriers are experienced, not merely observed; household income constraints and connectivity failures register differently for the learner than for the institution. Second, and more consequentially for policy, evidence that disability type shapes access implies that undifferentiated interventions will distribute their benefits unevenly. Establishing whether learners themselves perceive such differentiation is a necessary precursor to designing responsive interventions.

This study therefore surveys learners with disabilities in three Lagos State special schools to describe perceived socio-economic barriers to digital participation and to explore variation by gender and disability type. Its contribution is deliberately modest and descriptive: it provides a baseline account from a population whose own perspective is under-documented, and identifies the parameters that adequately powered research in this setting will need to address. It is offered as hypothesis-generating work rather than as a confirmatory test.

Research questions

1. What socio-economic factors do learners with disabilities identify as affecting their use of digital tools?

2. Do perceptions of accessibility, usability, digital literacy and socio-economic barriers differ by gender?

3. How do perceptions of accessibility, usability, digital literacy and socio-economic barriers vary across disability types?

Theoretical Framework

This study draws on three complementary perspectives, each addressing a different aspect of the problem.

The social model of disability holds that disability arises from environmental, institutional and attitudinal barriers rather than from impairment itself (Oliver, 1983, 1990). Applied to digital participation, it relocates the analytic question. The relevant issue is not what a learner with a visual impairment cannot do, but which features of the digital environment, inaccessible interfaces, absent screen-reader provision, untrained staff, produce exclusion. This framing motivates the study's focus on external constraints such as affordability and infrastructure.

The social model, however, offers limited purchase on why barriers of similar magnitude produce different outcomes for different individuals. Sen's (1999) capability approach supplies that. Its distinction between resources and the capability to convert resources into valued functionings is directly applicable: a smartphone is a resource, but converting it into digital participation requires connectivity, electricity, accessible software, relevant skills and permissive social attitudes. Mitra (2006, 2018) develops this into the human development model of disability, defining disability as deprivation of functionings or capabilities and treating impairment as itself shaped by resources and structural factors rather than as a fixed individual attribute. This framework accommodates the study's central expectation: that socio-economic conditions and disability type operate jointly, because they affect different points in the conversion process.

Finally, van Dijk's (2005) resources and appropriation theory specifies the mechanism linking social position to digital outcomes. Categorical inequalities produce unequal resource distribution, which in turn produces unequal access to digital technology across successive stages, motivation, physical access, skills and usage. Subsequent work distinguishes physical access from material access, encompassing device quality, peripherals and the recurring costs of maintaining connectivity (van Deursen & van Dijk, 2019). That distinction is pertinent here, since device ownership alone does not resolve the affordability problem when data and electricity remain recurrent expenses.

Taken together, these perspectives frame the study's variables as follows: socio-economic conditions and residential location function as resources and conversion factors; disability type conditions the efficiency of conversion; and accessibility, usability and digital literacy represent successive stages of appropriation.

Literature Review

Socio-economic conditions and digital access

Affordability is consistently identified as a primary constraint on digital participation among persons with disabilities. Duplaga's (2017) large-sample analysis found net income among the significant predictors of internet use, alongside education and occupational status, with place of residence exerting an independent effect. The residential effect is generally attributed to infrastructure: connectivity quality and electricity reliability vary geographically, and both are preconditions for sustained participation. Comparative work on rural digital literacy in Nigeria and China similarly locates the constraint less in device ownership than in affordability and infrastructural deficit, noting that nominal ownership often means outdated handsets incapable of supporting meaningful digital activity.

For persons with disabilities, these general constraints are compounded by the additional cost of assistive technology. Boot et al. (2018) identify cost, limited information and inadequate professional support among the principal barriers to assistive technology access for people with

intellectual disabilities. Fernández-Batanero et al. (2022), reviewing 31 studies, conclude that assistive technology does improve inclusion and accessibility for students with disabilities, while teacher training, information gaps and accessibility problems persist as barriers to realising that benefit.

Disability type and differential access

Evidence that access varies by disability type is well established and consequential for intervention design. Matter and Eide (2018) found disability type the strongest sociodemographic determinant of assistive technology access across two Southern African countries, and further observed that research and provision remain concentrated on mobility and vision, with hearing and communication technologies less studied and cognitive assistive technology almost entirely neglected. The Nigerian survey evidence is consistent: uptake was highest among learners with hearing impairment and learning disability, reflecting the relative availability of established technologies for those groups.

This asymmetry has a plausible explanation. Assistive technologies for visual and hearing impairment, screen readers, magnification, hearing aids, are comparatively mature, standardised and, in the case of screen-reading software, increasingly available at no cost through mainstream operating systems. Technologies supporting cognitive disability are less standardised, less well integrated into mainstream platforms and less familiar to educators. Where this asymmetry holds, undifferentiated digital inclusion programmes will tend to benefit learners whose needs are already best served.

Gender

Findings on gender are mixed and, in the disability literature, sparse. Studies of the general population in northern Nigeria document substantial gender gaps in internet access driven by social norms governing women's technology use. Whether comparable gaps hold among learners with disabilities, and whether they persist once socio-economic position is accounted for, is not established by the available evidence. This study treats gender as an exploratory question rather than testing a directional hypothesis.

Methodology

The study adopted a cross-sectional descriptive survey design suited to its exploratory aim of documenting perceptions within an under-researched population and generating hypotheses for future studies. A total of 38 learners were purposively selected from three special schools in Lagos State: Bethesda School of the Blind, Modupe Cole Memorial School and Step One Special Care Centre. The sample included 18 males and 20 females, with participants distributed across disability categories as follows: visual impairment (17), cognitive disability (14), hearing impairment (4) and mobility impairment (3). Data were collected using a researcher-designed questionnaire consisting of demographic items and four subscales measuring accessibility, perceived usability, digital literacy and socio-economic barriers, all rated on a four-point Likert scale. Content validity was ensured through expert review, while a pilot study produced a Cronbach's alpha of 0.84, indicating acceptable internal consistency.

Data analysis was conducted using descriptive statistics such as means and standard deviations. Gender differences were examined using independent samples t-tests, with Welch's correction applied where the assumption of equal variances was violated. Comparisons across disability types

were limited to descriptive analysis due to very small subgroup sizes, particularly for mobility and hearing impairments, and the presence of unequal variances across groups. As a result, inferential statistical testing for disability-based differences was not performed, and the findings in this regard should be interpreted with caution.

Results

Perceived socio-economic factors

Table 1: ***Item-level ratings of socio-economic factors affecting digital participation***

S/N	Item	M	SD
1	My income level affects my access to digital tools	3.02	0.59
2	Where I live limits my internet access	2.97	0.63
3	My family or community supports my digital learning	2.94	0.76
4	I know others like me who cannot afford digital devices	2.89	0.72
5	Gender affects access to digital tools among youth with disabilities	2.52	0.89

Note. Ratings on a four-point scale where higher scores indicate stronger agreement.

Table 1 presents item-level means for the socio-economic subscale. On a four-point scale, income level received the highest rating (M = 3.02, SD = 0.59), followed by residential location (M = 2.97, SD = 0.63). Family and community support recorded a comparable mean (M = 2.94, SD = 0.76), and awareness of peers unable to afford devices was similarly rated (M = 2.89, SD = 0.72). Gender received the lowest rating (M = 2.52, SD = 0.89) and the widest dispersion, indicating both lower perceived salience and greater disagreement among respondents on this item. These are descriptive ratings. The differences among the first four items are small relative to their standard deviations, and no test of the significance of those differences was conducted; the ordering should therefore be read as indicative rather than as an established ranking.

Gender comparisons

Table 2 reports independent-samples t-tests comparing male and female participants across the four measures. No comparison reached statistical significance at the .05 level. Female participants scored somewhat higher on accessibility and perceived usability, male participants somewhat higher on digital literacy, and the two groups were closely matched on socio-economic barriers.

These null results warrant careful interpretation. With 18 and 20 participants per group, the study has low statistical power and is capable of detecting only large effects. A non-significant result under these conditions is uninformative rather than evidence of equivalence: the data are consistent with there being no gender difference, but equally consistent with a small or moderate difference the study was unable to detect. The comparison on perceived usability ($p = .059$) falls just above the conventional threshold and should not be dismissed on that basis. No claim of gender parity in digital participation is made or supported here.

Table 2: Gender comparisons on accessibility, perceived usability, digital literacy and socio-economic barriers

Variable	Gender	*n*	*M*	*SD*	*t*	*df*	*p*
Accessibility	Male	18	13.00	4.06	−1.15	36.00	.256
	Female	20	14.50	3.95			
Perceived usability	Male	18	12.11	1.23	−1.99	23.87	.059
	Female	20	13.80	3.58			
Digital literacy	Male	18	15.89	1.91	1.69	30.55	.100
	Female	20	14.40	3.38			
Socio-economic barriers	Male	18	14.44	1.54	0.14	23.86	.893
	Female	20	14.30	4.49			

Note. Welch's correction applied where Levene's test indicated unequal variances; adjusted degrees of freedom are reported. No comparison was significant at $\alpha = .05$.

Variation by disability type

Table 3 presents descriptive statistics by disability type. A consistent ordering is apparent across all four measures: participants with mobility impairment recorded the highest means, followed by those with hearing impairment, then visual impairment, with participants with cognitive disability recording the lowest means throughout. The gap is widest on digital literacy, where the mobility and cognitive groups differ by nearly seven scale points.

Three features of these data constrain interpretation. First, the mobility ($n = 3$) and hearing ($n = 4$) subgroups are extremely small, and their means are correspondingly unstable; a single atypical respondent would shift them materially. Second, the mobility subgroup shows zero variance on all four measures, meaning all three participants returned identical subscale totals across four separate constructs. This pattern is unlikely to arise from independent responses and may indicate a recording or coding artefact; the subgroup's values should be treated as unreliable pending verification against the raw response data. Third, the consistency of the ordering across all four measures, while suggestive, could reflect a common underlying factor, including differential comprehension of the instrument itself, rather than four independent differences.

The descriptive pattern is therefore reported as an observation requiring confirmation, not as a finding. It is consistent with the established literature and with theoretical expectation, which lends it plausibility but does not substitute for adequately powered evidence.

Table 3: Descriptive statistics by disability type

Variable	Disability type	*n*	*M*	*SD*
Accessibility	Mobility	3	16.00	0.00
	Hearing	4	15.50	0.58
	Visual	17	13.24	1.92
	Cognitive	14	12.57	1.99
Perceived usability	Mobility	3	17.00	0.00
	Hearing	4	15.50	1.73
	Visual	17	13.35	2.80
	Cognitive	14	11.00	1.52
Digital literacy	Mobility	3	19.00	0.00
	Hearing	4	17.00	2.31
	Visual	17	16.41	0.80
	Cognitive	14	12.14	2.18
Socio-economic barriers	Mobility	3	20.00	0.00
	Hearing	4	17.50	2.89
	Visual	17	14.76	1.30
	Cognitive	14	11.79	3.29

Note. Descriptive statistics only. Inferential comparison was not conducted; subgroup sizes for mobility and hearing impairment are below the threshold for valid analysis of variance and between-group variances are markedly heterogeneous.

Discussion

Participants identified income as the most salient constraint on their digital participation, with residential location closely behind. This is consistent with Duplaga (2017), where net income and place of residence both predicted internet use in a nationally representative sample, and with the wider finding that cost is a principal barrier to assistive technology access (Boot et al., 2018; Fernández-Batanero et al., 2022). Read through van Dijk's (2005) resources and appropriation framework, the pattern is unsurprising: categorical inequality shapes resource distribution, which shapes access. The distinction between physical and material access (van Deursen & van Dijk, 2019) is instructive here, since the recurring costs of data and electricity, rather than one-off device acquisition, plausibly account for the coupling of income and location in participants' accounts. The moderate rating given to family and community support merits comment. Support was neither strongly present nor strongly absent, which under the capability approach is legible as a conversion factor operating at intermediate strength: household encouragement can facilitate the translation of a device into actual participation, but cannot compensate for the absence of the resource itself (Sen, 1999; Mitra, 2018).

The descriptive gradient across disability types aligns with Matter and Eide (2018), who found disability type the strongest sociodemographic determinant of assistive technology access in two Southern African countries, and with the Nigerian survey finding that uptake concentrates among learners with hearing impairment and learning disability. The relative disadvantage observed among participants with cognitive disability corresponds to a documented provision gap: assistive technologies for cognitive disability are less standardised and less integrated into mainstream platforms than those for sensory impairment, and the research base is correspondingly thin (Matter & Eide, 2018). If this gradient is real, it carries a clear implication, undifferentiated digital inclusion programmes will tend to benefit learners whose needs are already best served, widening rather than narrowing within-disability inequality.

That conditional is doing substantial work, and the alternative explanation must be taken seriously. A learner with cognitive disability may score lower because the questionnaire was harder to comprehend, not because participation is lower. This study cannot distinguish between those accounts. Doing so requires instruments validated separately within each disability group, and that requirement should be treated as a design constraint on subsequent work rather than as an afterthought. On gender, the study found no significant differences but is not powered to support any conclusion from that. The result is reported for completeness and to inform sample size planning in future research; it should not be cited as evidence of parity.

Conclusion

This exploratory study documented perceived socio-economic barriers to digital participation among 38 learners with disabilities in three Lagos State special schools. Participants identified income and residential location as the most salient constraints on their use of digital tools. Descriptively, learners with cognitive disabilities reported lower accessibility, usability, digital literacy and socio-economic scores than other groups, though subgroup sizes preclude inferential confirmation and measurement equivalence across groups is unestablished. No gender differences were detected, in a design lacking the power to detect any but large effects. The study's contribution lies in providing a descriptive baseline from a population whose own perspective is largely absent from the Nigerian literature, and in specifying the methodological requirements that adequately powered work in this setting must meet. Its findings should be read as hypotheses for testing rather than as conclusions established.

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ASSESSING THE ROLE OF DIGITAL ENTREPRENEURSHIP IN REDUCING UNEMPLOYMENT AMONG BUSINESS EDUCATION GRADUATES IN LAGOS STATE

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Abstract

This study investigated the digital entrepreneurship skills and employment creation among Business Education graduates in Lagos State, Nigeria. The study was necessitated by the persistent increase in graduate unemployment despite the introduction of entrepreneurship education into higher education curricula in Nigeria. Specifically, the study examined the relationship between digital entrepreneurship skills and employment creation, the relationship between entrepreneurship education and the utilization of entrepreneurial digital skills, and the relationship between business incubation programmes and employment creation among Business Education graduates in Lagos State. Three research questions and three corresponding null hypotheses guided the study. The study adopted a descriptive survey research design. The population comprised Business Education graduates in Lagos State, from which an appropriate sample was selected using a suitable sampling procedure. Data were collected using a structured questionnaire titled Digital Entrepreneurship Skills and Employment Creation Questionnaire (DESECQ). Descriptive statistics comprising frequency counts and percentages were used to answer the research questions while Pearson Product Moment Correlation (PPMC) and Chi-square statistics were used to test the hypotheses at the 0.05 level of significance. The findings revealed that there was a significant positive relationship between digital entrepreneurship skills and employment creation among Business Education graduates in Lagos State ($r = 0.73$, $p < 0.05$). The study also established a significant relationship between entrepreneurship education and the utilization of entrepreneurial digital skills among Business Education graduates ($r = 0.89$, $p < 0.05$). Furthermore, the findings showed a significant association between business incubation programmes and employment creation among Business Education graduates ($\chi^2 = 174.410$, $p < 0.05$). These findings indicate that digital entrepreneurship skills, effective entrepreneurship education, and business incubation programmes play significant roles in promoting employment creation among Business Education graduates. The study recommended that universities should strengthen practical digital entrepreneurship training, establish functional business incubation centres, integrate emerging digital technologies into the Business Education curriculum, and collaborate with government and industry partners to provide mentorship, funding opportunities and business support services for graduates.

Keywords: *Digital entrepreneurship skills, entrepreneurship education, business incubation programme, employment creation, Business Education graduates, Lagos State.*

Introduction

Entrepreneurship is a critical driver of economic growth, innovation, employment generation, and national development. It promotes the effective utilization of resources through the creation of new businesses that provide goods and services while addressing societal needs. In recent years, technological advancement has transformed entrepreneurship through the integration of digital technologies, giving rise to digital entrepreneurship. Digital entrepreneurship combines entrepreneurial competencies with digital skills to enable individuals to identify opportunities, develop innovative business solutions, and compete effectively in the digital economy (Boldureanu et al., 2020; Osiesi & Fajobi, 2019). Consequently, digital entrepreneurship has become an essential strategy for improving employability and promoting self-reliance among university graduates.

Digital entrepreneurship education equips learners with the knowledge, skills, and attitudes required to establish and sustain technology-driven enterprises. According to the European Commission (2018), digital entrepreneurial skills enable individuals to exploit digital opportunities, improve business efficiency, and adapt to the changing demands of the global economy. These competencies include information and communication technology (ICT), digital communication, online marketing, innovation, data management, and problem-solving skills, all of which are fundamental for business success in the Fourth Industrial Revolution. The acquisition of these skills enables graduates to create employment opportunities for themselves and others, thereby reducing dependence on scarce white-collar jobs.

Business Education is one of the vocational programmes offered in Nigerian universities with the primary objective of equipping students with entrepreneurial knowledge, practical competencies, and managerial skills for employment and self-employment. The programme prepares graduates for careers as educators, business managers, office professionals, and entrepreneurs. Universities have increasingly integrated entrepreneurship education into Business Education curricula to foster innovation, creativity, and enterprise development among students (Boldureanu et al., 2020). However, despite these efforts, evidence suggests that many graduates still lack adequate digital entrepreneurial competencies required to effectively participate in the contemporary digital economy.

Graduate unemployment remains one of the major socio-economic challenges confronting Nigeria. Although entrepreneurship education has become compulsory in higher institutions, many graduates continue to face difficulties in securing employment because of inadequate practical skills and the mismatch between university training and labour market expectations. Reports indicate that graduate unemployment remains relatively high, underscoring the need to strengthen entrepreneurial and digital competencies capable of promoting self-employment and business creation (Nigerian Bureau of Statistics, 2021). This situation has intensified the need for universities to produce graduates with relevant digital entrepreneurial skills that can stimulate innovation, enterprise creation, and sustainable economic development.

Business incubation programmes have also emerged as important institutional mechanisms for supporting entrepreneurial development. These programmes provide mentorship, networking opportunities, technical assistance, business development services, and access to funding that enhance the survival and growth of new enterprises (Jansen et al., 2015). By supporting graduates in transforming innovative ideas into viable businesses, business incubation programmes contribute significantly to employment creation, innovation, enterprise sustainability, and economic growth (Grimaldi & Grandi, 2005; UBI Global, 2019).

Given the increasing relevance of digital technologies in entrepreneurship and the persistent challenge of graduate unemployment in Nigeria, there is a growing need to assess the contribution of digital entrepreneurship to employment creation among Business Education graduates. Understanding the relationships among digital entrepreneurship skills, entrepreneurship education, business incubation programmes, and employment creation will provide valuable evidence for strengthening entrepreneurship education and promoting sustainable graduate employability in Lagos State.

1.2 Statement of the Problem

Due to poverty, discrimination, corruption, and the economic growth incapacity to supply jobs by the government, Nigerian's graduate unemployment problem has gotten worse in recent years. As a result, competition for existing available jobs has become more intense. As a necessary consequence of the densely populated country's poor social protection systems and inefficient and unsuccessful labour market policies, many of the country's youth are unable to find or create jobs, relying solely on their families for support, and are forced to do low-paid informal labour, as well as illegal work and crime. According to the World Bank (2019), 46% of college graduates and 39% of university graduates are unemployed or unable to find work within two years of graduation. It has been observed that institutions make adjustments to focus on generating graduates with abilities that are matched with industry requirements and the present employment market. However, the role of digital entrepreneurship is very important in reducing unemployment among business education graduates in Lagos state and Nigeria. Digital entrepreneurship skills are very important for developing new ideas in students for the world of work. They are expected to result in functional and improved living for individuals, creating jobs for themselves and being selfreliant.

Unfortunately, these digital entrepreneurship skills have not been well appropriated by Nigerian students, especially those in tertiary institutions, upon graduation. Many graduates were still waiting for white-collar jobs, which were inadequate for all graduates and rendered them jobless. An assessment of the role of digital entrepreneurship is necessary for improved and innovative instruction and students' adequate preparedness for the world of work and for reducing unemployment among business education graduates in universities. For this reason, this study is

imperative to investigate the role of digital entrepreneurship in reducing unemployment among business education graduates in Lagos state.

Purpose of the Study

The study's purpose is to investigate digital entrepreneurship's role in reducing unemployment among Business Education graduates in Lagos state. Specifically, the study will seek to;

1. identify the functional types of digital entrepreneurship programmes available to business education graduates.
2. examine the effects of digital entrepreneurship skills acquired by Business Education graduate in reducing unemployment rate in Lagos state.
3. investigate the extent to which graduates of Business Education utilize entrepreneurial digital skills in Lagos state.
4. determine the influence of business incubation programme on graduates' employment creation.

Research Questions

The study will answer the following research questions, namely;

1. What are the functional types of digital entrepreneurship programmes available to business education graduates?
2. What is the influence of digital entrepreneurship skills acquired by Business Education graduate in reducing unemployment rate in Lagos state?
3. To what extent do graduates of Business Education utilize entrepreneurial digital skills in Lagos state?
5. How does business incubation programme influence graduates' employment creation?

Research Hypotheses

The following null hypotheses were tested to provide answers to the research questions:

H_{01}: There is no significant relationship between the acquisition of digital entrepreneurship skills by Business Education graduates and unemployment reduction in Lagos State.

H_{02}: There is no significant relationship between entrepreneurship education and the utilization of entrepreneurial digital skills among Business Education graduates in Lagos State.

H_{03}: There is no significant association between participation in business incubation programmes and employment creation among Business Education graduates in Lagos State.

Reviewed of Related Literatures

This chapter reviewed some of the numerous works done by scholars and researchers directly related to this work.

Digital Entrepreneurship Skills and Employment Creation

Digital entrepreneurship skills comprise the technical and managerial competencies required to establish and sustain businesses in the digital economy. These include information and communication technology (ICT), digital marketing, data analysis, communication, innovation, critical thinking, business management, and problem-solving skills (Jain, 2024). Such competencies enable entrepreneurs to identify market opportunities, communicate effectively with customers, improve productivity, and remain competitive in rapidly changing business environments.

Several scholars have emphasized that the acquisition of digital entrepreneurial skills enhances graduates' employability and capacity for self-employment. Digital technologies facilitate online marketing, e-commerce, business networking, financial management, and customer relationship management, thereby improving business performance and employment generation (Kotler & Armstrong, 2014; Osiesi & Fajobi, 2019). Consequently, graduates possessing adequate digital entrepreneurial competencies are better positioned to establish successful enterprises and contribute to reducing unemployment.

Utilization of Entrepreneurial Digital Skills

The effective utilization of entrepreneurial digital skills depends largely on the quality of entrepreneurship education and graduates' ability to apply acquired competencies in real business situations. Entrepreneurial digital skills improve business planning, communication, innovation, collaboration, financial management, and customer service, thereby increasing business productivity and sustainability (Anckar, 2016; Van Laar & Deursen, 2018).

Studies have reported varying levels of digital skills utilization among university students. While Adeoye and Adeoye (2017), Amesi and Allison (2022), and Emeasoba, Akudolu, and Agbo (2022) found that Business Education students possess satisfactory digital competencies, Abdullahi (2020) and Okpokwasili (2019) reported inadequate utilization of digital skills due to limited exposure and insufficient practical training. These findings suggest the need for universities to strengthen practical digital entrepreneurship education to improve graduates' readiness for self-employment and the digital workplace.

Business Incubation Programmes and Employment Creation

Business incubation programmes are institutional support mechanisms established to assist entrepreneurs in developing sustainable business ventures. They provide shared facilities, mentorship, professional guidance, networking opportunities, financial support, and technical assistance that enhance business survival and growth (Bergek & Norrman, 2008; Jansen et al., 2015). Within higher education institutions, business incubation centres facilitate the commercialization of innovative ideas and promote entrepreneurial development among graduates (Grimaldi & Grandi, 2005).

Empirical evidence indicates that business incubation programmes contribute significantly to enterprise development, innovation, venture sustainability, and employment creation by reducing startup challenges and improving access to entrepreneurial resources (Hassan, 2020; Mian, 1996). Consequently, strengthening business incubation support in universities can enhance graduates' entrepreneurial success and reduce graduate unemployment.

Research Methodology

The study adopts a descriptive research design of survey type. Survey method of descriptive study was chosen because of the type of data collected through quantitative approach. The descriptive survey method was adopted to obtain information from Business Education Graduates. The target population of this study comprised all the one hundred and thirty five (135) Business Education Graduates in the Faculty of Education, University of Lagos, Akoka Lagos State, Nigeria during 2023/2024 session (Department Records, 2023). The study's sample size which is 135 was purposively selected. Hence, all the 135 from the Business Education graduates of the Faculty of Education of the university were used. As these were students whose curriculum majorly centers on entrepreneurship and digital skill acquisition. The sample size is 135 graduates representing the study's respondents. A structured questionnaire was employed as the primary data collection. The questionnaire was designed with multiple sections each corresponding to specific research questions related to the study. The data collected for this research was analyzed using descriptive statistics of tables, frequency counts, and simple percentages according to the demographic variables and research questions. In contrast, the inferential statistics of the Chi-square, and Pearson Product Moment Correlation Coefficient (PPMCC) were used to test the hypotheses stated earlier at a 0.05 level of significance.

Results

H_{01}: There is no significant relationship between the acquisition of digital entrepreneurship skills by Business Education graduates and unemployment reduction in Lagos State.

Table 4.3: Pearson Correlation

		Acquisition of digital entrepreneurship skills	**Unemployment reduction**
Acquisition of digital entrepreneurship skills	Pear. Correlation Sig.	1	0.73 .000
	N	135	
Unemployment reduction	Pear. Correlation Sig.	0.73 .000	1
	N	135	

Source: Researcher's Field Survey (2026)

The table above shows the value of correlation (r) to be 0.73 which is strong and positive correlation which means that there is significant relationship between the acquisition of digital entrepreneurship skills by Business Education graduates and unemployment reduction in Lagos State.

H_{02}: There is no significant relationship between entrepreneurship education and the utilization of entrepreneurial digital skills among Business Education graduates in Lagos State.

Table 4.4: Pearson Correlation

		Utilization of entrepreneurial digital skills	Entrepreneurship education
Utilization of entrepreneurial digital skills	Pear. correlation Sig.	1	0.89 .000
	N	135	
Entrepreneurship education	Pear. correlation Sig.	0.89 .000	1
	N	135	

Source: Researcher's Field Survey (2026)

The table above shows the value of correlation (r) to be 0.89 which is strong and positive correlation which means that there is significant relationship between entrepreneurship education and the utilization of entrepreneurial digital skills among Business Education graduates in Lagos State.

H_{03}: There is no significant association between participation in business incubation programmes and employment creation among Business Education graduates in Lagos State.

Table 4.5: Association Between Participation in Business Incubation Programmes and Employment Creation

Variables being Compared	N	P	DF	Critical X^2	Calculated X^2	Remark
Business Incubation Programmes Employment Creation	135	0.05	9	16.92	174.410	H0 Rejected

Source: Researcher's Field Survey (2026)

The result of X^2 showed that X^2 calculated value of 174.410[a] was greater than X^2 critical value of 16.92 which was significant at 0.05 given 9 degrees of freedom. The null hypothesis which states that there is no significant association between participation in business incubation programmes and employment creation among Business Education graduates in Lagos State was rejected and alternative hypothesis which says there is significant association between participation in business incubation programmes and employment creation among Business Education graduates in Lagos State was accepted.

Discussion of Findings

The findings of this study revealed that digital entrepreneurship skills, entrepreneurship education, and business incubation programmes are significantly related to employment creation among Business Education graduates in Lagos State. The results provide empirical evidence that strengthening entrepreneurial competencies and institutional support enhances graduates' capacity for self-employment and job creation. The first hypothesis revealed a significant positive relationship between digital entrepreneurship skills and employment creation among Business Education graduates. This implies that graduates who acquire digital entrepreneurial competencies are more likely to create employment opportunities and reduce unemployment. This finding is consistent with the studies of Ubulom and Meshack (2024), Amesi and Allison (2022), and Adeoye and Adeoye (2017), who found that digital and entrepreneurial skills improve graduates' employability and entrepreneurial success. The finding also supports McClelland's Need for Achievement Theory, which posits that individuals with strong achievement motivation are more likely to initiate innovative ventures that contribute to economic development.

The second hypothesis established a significant relationship between entrepreneurship education and the utilization of entrepreneurial digital skills among Business Education graduates. This indicates that entrepreneurship education equips graduates with the knowledge, confidence and

practical competencies required to effectively apply digital technologies in business activities. This finding agrees with Osiesi et al. (2024) and Emeasoba, Akudolu and Agbo (2022), who reported that entrepreneurship education enhances digital competence and the effective utilization of entrepreneurial digital skills among students. The finding equally supports the Entrepreneurial Intention Model of Boyd and Vozikis (1994), which emphasizes that entrepreneurship education strengthens entrepreneurial intentions and encourages graduates to apply acquired entrepreneurial competencies in establishing sustainable ventures.

The third hypothesis showed a significant association between business incubation programmes and employment creation among Business Education graduates. This suggests that business incubation programmes provide mentoring, technical support, networking opportunities and business development services that enhance graduates' ability to establish successful enterprises. This finding corroborates the studies of Hassan (2020), Mian (1996), and Wasdani (2022), who reported that business incubation programmes contribute significantly to venture creation, enterprise growth and employment generation. The finding further validates Gartner's New Venture Creation Theory (1985), which emphasizes that entrepreneurial success depends on the interaction of individual capabilities and supportive institutional environments, such as business incubation programmes.

Conclusion

Based on the findings of this study, it was concluded that digital entrepreneurship skills have become indispensable for enhancing the employability and entrepreneurial capacity of Business Education graduates in the contemporary digital economy. Graduates who possess adequate digital entrepreneurial competencies are better equipped to establish sustainable businesses, exploit emerging digital opportunities and contribute meaningfully to employment generation. The study further concluded that entrepreneurship education plays a significant role in promoting the effective utilization of entrepreneurial digital skills. Practical entrepreneurship education enhances graduates' confidence, creativity, innovation and ability to transform business ideas into viable enterprises. Similarly, business incubation programmes provide the necessary mentorship, technical support, networking opportunities and business development services that facilitate successful venture creation and employment generation. Overall, the study concludes that strengthening digital entrepreneurship education and expanding business incubation support within higher institutions will significantly improve selfemployment, reduce graduate unemployment and contribute to sustainable economic development in Lagos State and Nigeria at large.

Recommendations

Based on the findings and conclusions of this study, the following recommendations are made:

1. Universities offering Business Education programmes should review their curriculum to incorporate more practical digital entrepreneurship courses, including

digital marketing, e-commerce, data analytics, cloud computing and emerging digital technologies, to adequately prepare graduates for the evolving labour market.

2. University management and relevant educational agencies should establish functional business incubation centres equipped with modern digital facilities, experienced mentors and innovation hubs to support graduates in transforming business ideas into successful enterprises.

3. The Federal and State Governments**,** through relevant ministries and agencies, should provide financial support, start-up grants, soft loans and tax incentives for young entrepreneurs and Business Education graduates willing to establish digital enterprises.

4. The National Universities Commission (NUC) should periodically review the Business Education curriculum to ensure that digital entrepreneurship skills, innovation, artificial intelligence applications, digital business management and emerging technologies are adequately integrated into entrepreneurship education programmes.

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EVALUATING AI-ASSISTED RUBRIC GENERATION AND FEEDBACK SYSTEMS FOR AUTHENTIC ASSESSMENT IN NIGERIAN SECONDARY SCHOOLS

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Abstract

As educational ecosystems in developing nations transition from basic automation toward AI-augmented pedagogy, delivering timely, criterion-referenced feedback at scale remains a critical challenge in Nigerian secondary schools. This conceptual paper proposes a framework and research protocol for examining the pedagogical effectiveness, contextual alignment, and practical utility of leveraging Large Language Models (LLMs) to co-design authentic assessment rubrics and personalized feedback mechanisms tailored to the Nigerian Educational Research and Development Council (NERDC) curriculum standards. Drawing on a design-based research approach situated within a Technology Pedagogical Content Knowledge (TPACK) model, the paper specifies four evaluation dimensions for AI-generated assessment rubrics which are clarity, contextual feasibility, alignment with regional learning outcomes, and cultural bias mitigation, and argues, on the basis of the existing literature on large language models and algorithmic bias in education, that while AI tools carry clear potential to reduce the lesson-planning and grading workload of educators, human-in-the-loop oversight is essential to contextualize scoring criteria for local classroom realities and to guard against algorithmic bias. The paper further presents a structured prompt-engineering workflow intended to enable teachers to generate actionable, formative feedback adaptable to both high-tech and low-resource instructional settings, and concludes with strategic recommendations for integrating AI-supported assessment frameworks into Nigerian institutional policies and professional development programs, alongside a protocol for the empirical study that would test this framework directly.

Keywords: AI-Augmented Assessment, Authentic Learning, Nigerian Secondary Education, NERDC Curriculum, Rubric Co-Creation, Educational Technology.

Introduction

Authentic assessment has long been recognized as central to meaningful learning, yet its consistent implementation in resource-constrained classrooms remains elusive. In Nigerian secondary schools, teachers routinely manage large class sizes with limited time for individualized, criterion-referenced feedback, a constraint that pushes assessment practice toward summative, recall-based testing even when curriculum documents call for competency-based evaluation. The emergence of Large Language Models (LLMs) capable of generating structured text on demand introduces a new possibility: AI-assisted co-design of rubrics and formative feedback that preserves teacher judgment while reducing the mechanical burden of rubric drafting and comment-writing.

This shift mirrors a broader movement in educational technology research, in which generative AI is framed not as a replacement for instructional expertise but as a collaborative augmentation of it.

Kasneci et al. (2023) argue that large language models offer meaningful opportunities for personalized instruction and content generation, but caution that their outputs require pedagogical vetting before classroom use, particularly where training data under-represents local context. This tension between efficiency and contextual fidelity is especially pronounced in Nigeria, where curriculum standards set by the Nigerian Educational Research and Development Council (NERDC) reflect specific national learning outcomes, local languages, and sociocultural referents that generic, globally trained AI models may not adequately capture.

The present study therefore asks: to what extent can LLM-assisted rubric generation and feedback tools produce assessment artifacts that are pedagogically sound, curriculum-aligned, and free of cultural bias, when situated within a structured, teacher-supervised workflow? Framed within the Technology Pedagogical Content Knowledge (TPACK) model (Mishra & Koehler, 2006), the study treats AI competence as one strand of a teacher's broader pedagogical and content knowledge, rather than a standalone technical skill.

Statement of the Problem

Despite policy emphasis on authentic, competency-based assessment in Nigerian secondary education, teachers face persistent constraints that make individualized, criterion-referenced feedback difficult to sustain. AI-assisted rubric and feedback generation tools offer a potential efficiency gain, but without systematic evaluation of their contextual fit, there is a risk that such tools import assessment criteria, exemplars, or scoring logic misaligned with NERDC standards or with the lived realities of Nigerian classrooms. This study addresses that gap by evaluating AI-generated rubrics and feedback against explicit criteria of clarity, contextual feasibility, curriculum alignment, and bias mitigation.

Purpose and Objectives

The purpose of this study is to evaluate the pedagogical effectiveness, contextual alignment, and practical utility of AI-assisted rubric generation and feedback systems for authentic assessment in Nigerian secondary schools. Specifically, the study seeks to:

1. Examine the clarity and usability of AI-generated assessment rubrics for classroom teachers.

2. Assess the contextual feasibility of AI-generated rubrics within high-tech and low-resource instructional settings.

3. Evaluate the alignment of AI-generated rubrics with NERDC curriculum standards and regional learning outcomes.

4. Identify strategies for mitigating cultural and algorithmic bias in AI-generated assessment criteria.

5. Develop a structured prompt-engineering workflow that supports teacher-directed, human-in-the-loop rubric and feedback co-design.

Research Questions

1. How clear and usable do Nigerian secondary school teachers find AI-generated assessment rubrics?

2. How feasible are AI-generated rubrics and feedback workflows across differing levels of technological resourcing?

3. To what extent do AI-generated rubrics align with NERDC curriculum standards and regional learning outcomes?

4. What forms of cultural or algorithmic bias emerge in AI-generated rubrics, and how can human oversight mitigate them?

5. What prompt-engineering workflow best supports teacher-directed co-design of rubrics and formative feedback?

Literature Review

Authentic Assessment and Rubric-Based Evaluation

Authentic assessment emphasizes tasks that mirror real-world application of knowledge and skills, in contrast to assessment formats oriented primarily toward recall. Rubrics, as structured scoring tools that make performance criteria explicit, have been shown to support both the reliability of scoring and the transparency of expectations communicated to learners. Jonsson and Svingby (2007), in a review of rubric use in higher education, found that well-constructed, topic-specific rubrics can improve the reliability and validity of performance assessment while also serving a formative function by clarifying criteria for students in advance of a task. This dual function positions rubric quality as a critical variable in any AI-assisted rubric generation workflow, since a rubric that is efficient to produce but poorly specified may undermine both purposes.

Large Language Models in Educational Practice

The rapid uptake of large language models in education has generated both enthusiasm and caution among researchers. Kasneci et al. (2023) reviewed the opportunities and challenges that LLMs such as ChatGPT present for teaching and learning, noting their capacity to generate instructional materials, explanations, and feedback rapidly, while also flagging risks around factual inaccuracy, bias embedded in training data, and the potential erosion of critical engagement if outputs are adopted uncritically. These concerns are directly relevant to rubric generation: an LLM may produce a fluent, well-formatted rubric whose criteria nonetheless reflect assumptions, exemplars, or standards drawn from contexts different from the one in which it will be used. The literature therefore consistently frames LLM output as a draft to be reviewed and adapted by a knowledgeable practitioner, rather than a finished instructional artifact.

Algorithmic and Cultural Bias in AI-Assisted Education

A parallel strand of research examines how bias enters AI systems used in educational contexts. Baker and Hawn (2022) documented how algorithmic bias in education can arise not only from skewed training data but also from mismatches between the context in which a model was

developed and the context in which it is deployed, producing outputs that may disadvantage or misrepresent particular groups of learners. In a Nigerian secondary school context, this risk manifests as rubrics or feedback that assume resources, examples, or cultural referents unfamiliar to local learners, or that implicitly penalize non-native English phrasing in ways unrelated to the construct being assessed. This body of work underlines why human-in-the-loop review, rather than direct classroom deployment of AI output is treated as a non-negotiable design principle in the present study.

The TPACK Model as a Framework for AI Integration

Mishra and Koehler's (2006) Technology, Pedagogy, and Content Knowledge (TPACK) framework conceptualizes effective technology integration as the intersection of technological knowledge, pedagogical knowledge, and content knowledge, rather than as technological competence in isolation. Applied to AI-assisted assessment, TPACK suggests that a teacher's ability to use an LLM productively for rubric generation depends jointly on understanding what the tool can technically do, how rubrics function pedagogically, and what the specific curriculum content requires.

Design-Based Research in Educational Technology

Design-based research (DBR) is an iterative methodology in which interventions are designed, implemented, evaluated, and refined in real educational settings, generating both a practical solution and theoretical insight into the conditions of its use. Anderson and Shattuck (2012), reviewing a decade of design-based research in education, describe the approach as well suited to studying emerging technologies in situ, precisely because it accommodates iterative refinement as unanticipated contextual factors surface. This methodological orientation aligns closely with the present study's aim of evaluating and refining an AI-assisted rubric and feedback workflow under real classroom constraints rather than in a controlled, decontextualized setting.

Gap in the Literature

While the international literature addresses LLM use in education broadly, and Nigerian education technology research has examined teacher readiness and digital literacy integration in general terms, there remains limited empirical work evaluating AI-assisted rubric generation and feedback specifically against NERDC curriculum standards and the resourcing realities of Nigerian secondary schools. This study addresses that gap directly.

Methodology

This study adopts a design-based research (DBR) approach, situated within the TPACK framework, to iteratively design, implement, and evaluate an AI-assisted rubric and feedback generation workflow in Nigerian secondary school settings.

Research Design

A design-based research approach was selected because it allows the AI-assisted workflow to be evaluated and refined across successive cycles of use, capturing both the pedagogical effectiveness of the tool and the practical constraints of the classrooms in which it is deployed. Each cycle involves: (a) collaborative rubric generation using a structured LLM prompting protocol, (b) teacher review and contextual adaptation of the AI-generated rubric, (c) classroom application to authentic assessment tasks, and (d) structured evaluation of the resulting rubric and feedback artifacts.

Participants and Sampling

Participants comprise secondary school teachers drawn from public secondary schools across Lagos State, selected through stratified sampling to ensure representation across the state's Education Districts and across subject specializations. Stratification by district and subject area allows the study to capture variation in resourcing (high-tech versus low-resource instructional settings) that is central to the feasibility research question.

The AI-Assisted Rubric and Feedback Workflow

The workflow centers on a structured prompt-engineering protocol through which teachers specify the learning outcome, subject content, and assessment task, and the LLM proposes a draft rubric with criterion descriptors across performance levels. Teachers then review the draft against four evaluation dimensions revising or rejecting AI-proposed criteria as needed before classroom use. The same protocol supports generation of draft formative feedback comments keyed to individual student submissions, which teachers likewise review and personalize prior to release.

Instrumentation

Rubric and feedback quality are evaluated using a structured evaluation instrument covering the four dimensions specified in the research questions: clarity and usability, contextual feasibility, curriculum alignment, and bias mitigation. Teacher perceptions of the workflow are captured through a structured questionnaire and semi-structured interviews, supplemented by document analysis comparing AI-generated rubrics against published NERDC curriculum standards for the relevant subjects.

Data Analysis

Quantitative questionnaire data are analyzed descriptively and, where appropriate, through comparative statistics across school resourcing categories. Qualitative interview and document-analysis data are analyzed thematically, with particular attention to instances where teachers modified or rejected AI-generated rubric criteria, since these instances are treated as direct evidence of contextual misalignment requiring human correction.

Ethical Considerations

The study follows standard human-subjects research protocols, including informed consent, voluntary participation, and anonymization of teacher and school identifying information. Because the study involves evaluation of AI-generated content for potential bias, particular care is taken to ensure that any biased or inappropriate AI outputs identified during the study are documented for research purposes but are not deployed in actual classroom assessment of students.

Discussion: Anticipated Contributions and Implications

This paper is conceptual and protocol-based: it proposes a framework and a research design rather than reporting completed empirical results. No rubrics, feedback artifacts, or teacher data have yet been collected under the workflow described above. The discussion that follows outlines the reasoning, grounded in the literature reviewed, for why the proposed framework is expected to matter, and identifies the specific empirical questions the subsequent study is designed to test. Reported findings should not be inferred from this discussion; they will only be available once the design-based research cycles described in the Methodology section have been carried out.

Drawing on Kasneci et al.'s (2023) analysis of LLM capability and risk, the proposed workflow is expected to test whether AI assistance produces measurable efficiency gains in the drafting stage of rubric and feedback generation, without corresponding losses in criterion quality. Drawing on Baker and Hawn's (2022) work on contextual mismatch in algorithmic systems, the study is designed to test the hypothesis that AI-generated drafts will require teacher revision in areas involving locally specific exemplars, language expectations, and resourcing assumptions which, if confirmed, would support the paper's central argument that human-in-the-loop oversight, rather than direct AI deployment, is necessary for contextually valid authentic assessment in Nigerian secondary schools. These remain testable propositions, not findings, until the protocol is executed.

The framework also anticipates that contextual feasibility may differ between high-tech and low-resource school settings, particularly regarding the practicality of digital rubric delivery and feedback platforms versus print-based adaptations of the same AI-generated content. Whether this difference materializes is an empirical question for the planned study; if it does, it would reinforce the TPACK framework's premise that technological knowledge alone is insufficient, and would suggest that teachers in low-resource settings need explicit pedagogical strategies for translating AI-generated digital artifacts into classroom-usable forms.

Conclusion and Recommendations

This paper has proposed a conceptual framework and research protocol for evaluating AI-assisted rubric generation and feedback systems for authentic assessment in Nigerian secondary schools, framed within the TPACK model and organized around a structured, human-in-the-loop prompt-engineering workflow. Its central premise is that LLMs can meaningfully reduce the workload associated with rubric and feedback drafting, but only when paired with sustained teacher oversight capable of correcting for contextual misalignment and algorithmic bias.

Even in advance of empirical testing, the framework developed here supports several preliminary recommendations for Nigerian educational institutions: (a) begin integrating AI-assisted

assessment literacy into teacher professional development programs, including training on reviewing AI output for curriculum alignment and bias; (b) develop institutional guidelines specifying human-in-the-loop review as a mandatory step before any AI-generated rubric or feedback is used with students; and (c) plan for low-bandwidth or print-adaptable delivery mechanisms so that AI-assisted assessment tools remain equitable across differently resourced schools. The immediate next step for this line of research is to execute the design-based research cycles described in the Methodology section and report the resulting empirical findings.

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STUDENTS AND INTELLIGENT MACHINES: WHAT TO EXPECT, WHAT COULD GO RIGHT, AND WHAT COULD GO WRONG IN THE FUTURE OF LEARNING DURING THE FIFTH INDUSTRIAL REVOLUTION

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Abstract

The growing integration of intelligent machines into education during the Fifth Industrial Revolution offers real opportunities for personalised, accessible, and augmented learning, yet it also raises serious concerns about psychological wellbeing, eroded critical thinking, and ethical risks such as bias and privacy. This study addresses the need to examine both the promises and pitfalls of this shift, clarifying what students and educators can expect as intelligent machines increasingly shape the future of learning. Anchored in Activity Theory, which conceptualises learning as a socially mediated activity system involving subjects, tools, rules, community, and division of labour, the study investigates how intelligent machines function as mediating artefacts that reshape students' learning experiences, engagement, and knowledge construction. Adopting a qualitative research design, the study analyzed twelve publicly available YouTube videos featuring interviews, lectures, and discussions from established sources, using deductive thematic analysis guided by six a priori themes derived from the study's purposes. Findings reveal that intelligent machines are expected to transform education through real-time monitoring, immersive technologies, and personalized adaptive tutoring, offering opportunities for expanded accessibility and diagnostic precision. Positive prospects include AI functioning as a "tool for thought" that strengthens human reasoning, keeping learners central to their own work, and supporting critical thinking through argument-testing and reflective prompting. However, the findings also expose significant risks, including psychological pressure from continuous biometric surveillance, the blurring of boundaries between augmentation and automation as autonomous agents take on greater independent action, homogenised "hive mind" thinking, erosion of metacognition, and ethical challenges surrounding data privacy, biometric reliability, and regional bias in AI systems. The study concludes that the trajectory of learning in the 5IR will depend on how deliberately institutions design AI systems and policies to preserve human agency, judgment, and oversight. Recommendations include expanding equitable access to immersive technologies, embedding reflective and challenge-oriented design principles into AI tools, and establishing dedicated ethics governance structures to ensure that intelligent machines enhance, rather than diminish, the human-centred goals of education.

Keyword: Hive mind, tool for thought; intelligent machine; 5IR; future of learning

Introduction

Technology and education have evolved significantly over time, with technological innovations continuously transforming how knowledge is created, accessed, and shared. The emergence of artificial intelligence (AI), automation, robotics, and intelligent digital systems represents a major shift in educational practices, creating new possibilities for enhancing teaching and learning processes. Unlike previous industrial revolutions that primarily focused on automation, productivity, and efficiency, the Fifth Industrial Revolution (5IR) introduces a human-centered approach that emphasises collaboration between humans and intelligent machines to enhance human capabilities while preserving creativity, ethical reasoning, empathy, and social values (Noble et al., 2022). Within this emerging educational landscape, intelligent machines are increasingly positioned not as replacements for teachers or students but as mediating technological tools that transform how learning activities are organized, experienced, and developed.

The transformation of education during the Fifth Industrial Revolution can be understood through the lens of Activity Theory, which conceptualises learning as a socially situated and culturally mediated activity involving interactions among subjects, objects, tools, rules, community, and division of labour (Vygotsky, 1978; Engeström, 1987). From this perspective, students represent the subjects engaged in learning activities, while knowledge acquisition, skill development, and academic achievement constitute the objects of the activity system. Intelligent machines, including AI-powered tutoring systems, generative AI applications, adaptive learning platforms, educational robots, and learning analytics systems, function as mediating artefacts that influence how students interact with knowledge, teachers, peers, and learning environments. Therefore, the integration of intelligent technologies does not merely introduce new tools into education but restructures the entire learning activity system by altering patterns of interaction, decision-making, and knowledge construction.

Within contemporary and future learning environments, intelligent machines are expected to reshape the relationship between learners, educational objectives, and learning processes. Through AI-supported systems, students may receive personalized learning pathways based on their prior knowledge, learning preferences, cognitive development, and academic progress (Tan et al., 2025). From an Activity Theory perspective, these technologies mediate the relationship between students and learning objectives by providing adaptive feedback, recommending resources, identifying learning difficulties, and supporting independent knowledge construction. Rather than requiring all learners to follow standardized instructional approaches, intelligent systems enable dynamic learning activities where students actively engage with personalized resources and participate in continuous knowledge development.

The principle of human–AI collaboration through augmentation rather than automation represents a significant transformation within the educational activity system. Intelligent machines are expected to enhance, rather than replace, human cognitive and pedagogical capabilities by providing personalised explanations, generating learning resources, identifying learning gaps, and supporting instructional decision-making (Raj et al., 2026). Within this framework, teachers remain central participants in the activity system, providing professional judgment, emotional support, ethical guidance, and mentorship, while AI systems contribute computational capabilities such as data analysis, prediction, and adaptive recommendations (Wang & Li, 2026). Consequently, the division of labour between teachers, students, and intelligent systems is expected to evolve from traditional teacher-centered models toward collaborative arrangements where human and machine capabilities complement one another.

Activity Theory further emphasizes that learning activities are influenced by the social and cultural context in which they occur. In the Fifth Industrial Revolution, the community and rules surrounding education—including institutional policies, ethical guidelines, digital literacy expectations, and responsible AI practices—will significantly determine how intelligent machines are adopted and utilized. Although AI technologies provide opportunities for improving engagement, accessibility, and learning outcomes, contradictions may emerge within the activity system. These contradictions include concerns about algorithmic bias, academic integrity, data privacy, unequal access to technology, and excessive dependence on automated systems (Júnior et al., 2025). From an Activity Theory perspective, these tensions are not simply barriers but opportunities for transformation, requiring educational stakeholders to redesign practices, policies, and competencies to achieve meaningful human–AI collaboration.

Another important transformation concerns the development of students' competencies within AI-enabled learning environments. Future learners will require more than disciplinary knowledge; they will need AI literacy, critical thinking, creativity, ethical reasoning, communication skills, adaptability, and the ability to evaluate and collaborate with intelligent systems (Biagini, 2025). In Activity Theory terms, students are not passive users of technological tools but active participants who negotiate, interpret, and transform mediated learning activities. Their ability to critically engage with AI-generated information, question algorithmic recommendations, and integrate technological support into their reasoning processes will determine the effectiveness of future learning systems.

The Fifth Industrial Revolution also presents possibilities for creating more inclusive and equitable learning activity systems. Intelligent machines can support learners through multilingual technologies, assistive applications, automated feedback systems, and accessible learning resources for diverse student populations. When guided by ethical principles and inclusive implementation strategies, AI-supported learning environments may reduce educational barriers and expand participation among learners from different social, economic, linguistic, and physical backgrounds. Thus, intelligent machines have the potential to transform education into a more adaptive, participatory, and inclusive activity system.

Activity Theory provides a suitable lens for explaining how intelligent machines reshape learning processes during the Fifth Industrial Revolution by conceptualizing education as a dynamic activity system involving interacting components: subjects, objects, mediating tools, rules, community, division of labour, and outcomes (Vygotsky, 1978; Engeström, 1987). In this study, students represent the subjects who actively engage in learning activities, while the primary object is the development of knowledge, skills, creativity, critical thinking, and meaningful learning experiences. Intelligent machines, including artificial intelligence applications, adaptive learning systems, generative AI tools, and educational robots, function as mediating tools that transform how students interact with learning resources and construct knowledge. Through this mediation process, AI technologies support personalized learning by analysing students' abilities, preferences, progress, and learning difficulties, thereby enabling adaptive content delivery, individualized feedback, and differentiated learning pathways. According to Activity Theory, the effectiveness of a tool depends on how it mediates human activity within a particular social context rather than on the technology itself (Engeström, 1987). Therefore, intelligent machines contribute to improved learning outcomes when they are purposefully integrated into educational practices that support students' cognitive development, autonomy, and engagement.

Furthermore, Activity Theory explains human–AI collaboration, collaborative intelligence, student engagement, critical thinking, and ethical AI use as interconnected elements within the

learning activity system. Human–AI collaboration represents a transformation in the division of labour, where intelligent machines perform tasks such as information processing, pattern recognition, and feedback generation, while students and teachers contribute uniquely human abilities including creativity, judgment, reflection, and ethical reasoning. Rather than replacing human participation, AI serves as an augmenting tool that expands learners' capabilities and supports higher-order thinking (Engeström, 2001).

Student engagement emerges through meaningful interaction between learners, technological tools, peers, and educators within the learning community, while critical thinking develops as students evaluate, interpret, and critically reflect on AI-generated information rather than passively accepting machine outputs. The rules component of Activity Theory represents ethical guidelines, institutional policies, digital literacy practices, and responsible AI principles that regulate interactions between learners and intelligent systems. Thus, ethical AI implementation ensures that issues such as privacy, bias, accountability, and academic integrity are addressed while maintaining human agency. Consequently, Activity Theory provides a comprehensive explanation of how intelligent machines, when embedded within supportive educational communities and governed by appropriate rules, can facilitate adaptive, collaborative, and transformative learning experiences during the Fifth Industrial Revolution (Loose et al., 2022).

Despite these opportunities, existing research on artificial intelligence in education has largely focused on technology acceptance, system performance, and the functional capabilities of AI applications, with limited attention given to the broader social and educational processes through which students, teachers, and intelligent machines collaboratively construct learning experiences (Mustafa et al., 2024; Wang & Li, 2026). Furthermore, insufficient conceptual attention has been given to understanding how AI integration transforms the relationships among learners, learning objectives, technological tools, educational communities, and institutional structures within the human-centered philosophy of the Fifth Industrial Revolution (Li & Tian, 2026; Nguyen & Elbanna, 2025; Khac & Leyer, 2025; Eisbach et al., 2023). Therefore, applying Activity Theory provides a comprehensive framework for examining how intelligent machines function as mediating tools, how learning activities are transformed, and how human agency can be preserved within AI-supported educational environments. This study therefore seeks to explore students and intelligent machines as interconnected elements of a dynamic learning activity system, highlighting how human–AI collaboration can contribute to personalized, inclusive, and transformative learning experiences during the Fifth Industrial Revolution.

Purposes of the Study

The study seeks to:

1. Examine how intelligent machines influence students' learning experiences during the Fifth Industrial Revolution.
2. Explore the role of human–AI collaboration in enhancing students' learning through augmentation rather than automation.
3. Investigate how intelligent machines contribute to personalized learning, student engagement.
4. Assess the extent to which collaborative intelligence between students and AI systems can promote critical thinking.
5. Examine the importance of shared decision-making between humans and intelligent machines in AI-supported educational environments.
6. Identify ethical challenges associated with the integration of intelligent machines into education.

Research Questions

The following research questions will guide the study:

1. How do intelligent machines influence students' learning experiences during the Fifth Industrial Revolution?
2. What role does human–AI collaboration play in enhancing students' learning through augmentation rather than automation?
3. How do intelligent machines contribute to personalized learning and student engagement?
4. To what extent does collaborative intelligence between students and AI systems promote critical thinking?
5. What is the importance of shared decision-making between humans and intelligent machines in AI-supported educational environments?
6. What ethical challenges are associated with the integration of intelligent machines into education?

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Literature Review

Theoretical Framework

Activity Theory, developed from the sociocultural tradition of Vygotsky and expanded by Engeström (1987), provides a suitable theoretical foundation for examining the relationship between students and intelligent machines during the Fifth Industrial Revolution. The theory conceptualizes learning as a dynamic, socially situated activity system in which human actions are mediated by tools, cultural practices, rules, communities, and objectives. In the context of AI-supported education, intelligent machines represent emerging technological tools that mediate students' learning activities by providing adaptive feedback, personalized resources, knowledge support, and opportunities for collaborative problem-solving. Rather than viewing AI as a replacement for human intelligence, Activity Theory positions intelligent machines as mediating artefacts that transform the ways students interact with knowledge, teachers, peers, and learning environments. Therefore, the theory provides a basis for understanding how intelligent machines influence students' learning experiences, engagement, and knowledge construction during the Fifth Industrial Revolution (Vygotsky, 1978; Engeström, 1987).

The relevance of Activity Theory to this study is further demonstrated through its emphasis on interactions among the components of an activity system: the subject (students), object (learning goals and knowledge development), mediating tools (intelligent machines and AI technologies), community (teachers, peers, educational institutions, and technology providers), rules (ethical guidelines, institutional policies, and digital practices), and division of labour (shared responsibilities between humans and intelligent systems). Through this perspective, human–AI collaboration is understood as a process of co-activity where students use intelligent machines to enhance critical thinking, decision-making, creativity, and problem-solving rather than surrendering cognitive responsibility to technology. Activity Theory also supports the investigation of ethical challenges associated with AI integration, including issues of accountability, transparency, privacy, and equitable access, because changes introduced by intelligent technologies often create tensions and require the reorganization of existing educational practices. Thus, Activity Theory offers a comprehensive lens for examining how intelligent machines reshape learning activities, promote collaborative intelligence, and influence the future of education in the Fifth Industrial Revolution (Lee & Granziera, 2026).

Intelligent Machines and Students' Learning Experiences

The integration of intelligent machines into education has become one of the defining characteristics of twenty-first-century teaching and learning. Intelligent machines refer to AI-powered technologies capable of performing cognitive functions such as reasoning, learning, decision-making, natural language processing, and adaptive problem-solving (Taherdoost, 2025). In educational settings, these technologies include intelligent tutoring systems, generative AI tools, educational robotics, adaptive learning platforms, virtual and augmented reality, and learning analytics. These technologies have shifted educational practices from traditional teacher-centered instruction toward learner-centered environments where students receive personalized learning experiences tailored to their individual needs and learning preferences (Otto et al., 2023). During the Fifth Industrial Revolution (5IR), intelligent machines are increasingly viewed not merely as technological tools but as collaborative partners capable of enhancing students' cognitive abilities, creativity, and lifelong learning competencies while preserving the central role of human intelligence (Ziatdinov et al., 2024).

The concept of students' learning experiences extends beyond academic achievement to include students' cognitive, emotional, behavioral, and social interactions throughout the learning process (Vugteveen et al., 2025). Positive learning experiences are characterized by active engagement, meaningful participation, critical thinking, motivation, collaboration, and knowledge construction. educational research suggests that AI technologies can significantly improve these experiences through personalized instruction, adaptive assessment, intelligent feedback, and continuous academic support (Fortuna et al., 2025). For example, intelligent tutoring systems provide individualized explanations based on learners' performance, while learning analytics identify students at risk of poor academic outcomes and recommend timely interventions (Huang et al., 2025). These developments suggest that intelligent machines can facilitate more effective learning experiences when integrated within sound pedagogical frameworks.

However, scholars have also cautioned that the educational value of intelligent machines depends on how they are implemented. Chan and Tsi (2024) argues that AI should not be regarded as a substitute for teachers because education involves social interaction, emotional support, ethical guidance, and cultural understanding that remain uniquely human. Similarly, Wang and Li (2026) noted that while AI has the potential to improve educational efficiency, excessive dependence on intelligent systems may reduce students' opportunities to develop independent reasoning, creativity, and critical thinking. Consequently, current literature increasingly emphasizes human-centered AI integration rather than technological replacement.

Human–AI Collaboration Through Augmentation Rather Than Automation

Human–AI collaboration has emerged as one of the most influential concepts in discussions of AI-enhanced education. The Human–AI Collaboration argues that the greatest educational benefits occur when artificial intelligence complements rather than replaces human intelligence (Atchley et al., 2024). This perspective reflects the philosophy of the Fifth Industrial Revolution, which emphasizes collaboration between humans and intelligent technologies to improve creativity, innovation, and societal well-being (Noble et al., 2022). Within educational environments, augmentation refers to using AI systems to strengthen students' cognitive capabilities while allowing learners to maintain control over reasoning, decision-making, and knowledge construction.

Research indicates that AI-supported augmentation enhances learning by providing personalized recommendations, automated feedback, content generation, language translation, and intelligent

tutoring without eliminating the role of human educators (Fortuna et al., 2025). Raj et al. (2026) describe this relationship as the automation–augmentation paradox, explaining that while AI can automate routine tasks, its greatest value lies in augmenting human judgment and creativity. In education, this enables teachers to devote more attention to mentoring, facilitating collaborative learning, and supporting students' emotional and social development. Consequently, AI becomes a learning partner that enhances rather than replaces educational interactions.

Intelligent Machines, Personalized Learning, and Student Engagement

Personalized learning has become one of the most widely recognized applications of artificial intelligence in education. Personalized learning refers to instructional approaches that adapt educational content, pace, assessment, and learning pathways according to individual students' characteristics, needs, and abilities (Inthanon & Wised, 2024). AI-powered adaptive learning systems continuously analyze students' learning behaviors and provide customized instructional support that addresses individual weaknesses while reinforcing strengths. Such adaptive capabilities allow learners to progress at their own pace and receive immediate feedback, thereby improving motivation and learning outcomes (Gligorea et al., 2023).

Student engagement is equally important because it reflects learners' cognitive investment, emotional commitment, and active participation in educational activities (Fasco et al., 2024). AI technologies contribute to engagement by making learning more interactive, responsive, and accessible. Intelligent tutoring systems, gamified learning environments, conversational AI, and immersive virtual learning experiences encourage students to participate actively in learning rather than passively receiving information (Latif et al., 2026). Nevertheless, researchers caution that excessive reliance on AI-generated responses may encourage superficial engagement if students become dependent on intelligent systems without critically evaluating the information they receive (Tian & Zhang, 2025; Zhai et al., 2024).

Collaborative Intelligence and Critical Thinking

Collaborative intelligence refers to the combined capabilities generated when humans and intelligent machines work together to solve problems and make decisions (Schleiger et al., 2024). Rather than viewing AI as an independent decision-maker, collaborative intelligence positions intelligent machines as cognitive partners that complement human reasoning. In educational settings, collaborative intelligence enables students to explore multiple perspectives, analyze complex datasets, generate creative ideas, and receive intelligent recommendations while retaining responsibility for evaluating and applying knowledge.

Critical thinking remains one of the most important competencies required for success during the Fifth Industrial Revolution. According to Salido et al. (2025), critical thinking involves interpretation, analysis, evaluation, inference, explanation, and self-regulation. AI technologies can strengthen these abilities by exposing learners to diverse viewpoints, facilitating inquiry-based learning, and supporting problem-solving activities. However, if students rely exclusively on AI-generated outputs without questioning their accuracy or validity, critical thinking may be weakened (Abubakar et al., 2025). Therefore, educational institutions must emphasize AI literacy and critical evaluation skills to ensure that collaborative intelligence enhances rather than diminishes students' cognitive development.

Shared Decision-Making in AI-Supported Educational Environments

Shared decision-making is a fundamental principle of the Human–AI Collaboration because it ensures that humans maintain authority over decisions supported by artificial intelligence. In

educational contexts, AI systems can analyze learning behaviors, predict academic performance, recommend instructional strategies, and identify students requiring intervention (Dong et al., 2025). However, these recommendations should support rather than replace the professional judgment of teachers and the autonomy of learners.

Nizamani et al. (2025) argues that human-centered AI requires humans to remain accountable for educational decisions because AI systems lack contextual understanding, ethical reasoning, and emotional intelligence. Teachers possess knowledge of learners' social, emotional, and cultural backgrounds that cannot be fully captured through algorithms. Consequently, effective AI-supported learning environments require collaborative decision-making in which intelligent machines provide evidence-based recommendations while teachers and students interpret, validate, and implement those recommendations appropriately.

Ethical Challenges Associated with Intelligent Machines in Education

The increasing integration of intelligent machines into education has generated significant ethical concerns. One of the most widely discussed issues involves data privacy, as AI systems often collect and analyze large volumes of student information to personalize learning experiences (Martin & Zimmermann, 2024). Without appropriate safeguards, these data may be vulnerable to misuse, unauthorized access, or breaches of confidentiality. Algorithmic bias also presents challenges because AI systems may reproduce biases embedded in training datasets, potentially leading to unfair educational recommendations or discriminatory outcomes (Arora et al., 2023).

Academic integrity has become another major concern with the widespread availability of generative AI technologies capable of producing essays, programming code, and problem solutions. While these tools can support learning, they also create opportunities for plagiarism and reduced independent thinking if used irresponsibly (Balalle & Pannilage, 2025). Furthermore, unequal access to intelligent technologies may widen existing educational inequalities, particularly in developing countries where digital infrastructure remains inadequate (Wang et al., 2024). Memarian and Doleck (2023) therefore recommends that educational institutions establish ethical AI policies emphasizing transparency, accountability, fairness, inclusiveness, and responsible innovation.

Methodology

This study adopted a qualitative research design employing secondary data analysis of publicly available YouTube video content to explore how intelligent machines are shaping education and industry during the Fifth Industrial Revolution, a design well suited to exploring meaning, perspective, and pattern within existing textual data rather than generating new primary data through direct participant interaction. The data comprised twelve (12) publicly accessible YouTube videos featuring interviews, lectures, and discussions by subject-matter speakers, sourced from established channels including IBM Technology, The Wall Street Journal, TED, TEDx, and Bloomberg Originals, among others, and were selected using a purposive sampling strategy guided by relevance criteria requiring that each video substantively address the influence of intelligent machines or AI on learning, work, or the Fifth Industrial Revolution. Audio content from each selected video was transcribed, after which all personal names of speakers, interviewees, and third parties were anonymized and replaced with standardized generic labels (e.g., Speaker 1, Interviewee 1, Third Party 1) to protect contributor identity while preserving the technical and substantive content of each discussion; the resulting anonymized transcripts were then analyzed using deductive thematic analysis, in which six a priori themes derived from the study's stated

purposes were used as the analytical framework to organize and interpret sub-themes and illustrative statements emerging from the data. Trustworthiness was strengthened by grounding every identified sub-theme in a directly traceable, quoted statement from the anonymized transcripts, ensuring that interpretations remained closely tied to the original data rather than researcher inference alone; and because the data derived from publicly available video content, formal participant consent was not required, though ethical rigor was maintained through the systematic anonymization of all identifying information prior to analysis and reporting.

Data Analysis and Result

Table 1: Demographic Information of Participants

Label	Source	Professional Role / Demographic	Expertise / Context
Speaker 1	Source 1	Adjunct Professor	AI educational strategist and expert in legacy vs. modern skill evolution.
Speaker 1	Source 2	Presenter	Host detailing the implementation of neuro-monitoring in education.
Interviewee 1	Source 2	Neural Scientist	Expert at a research institution specializing in brain neurons and EEG technology.
Interviewee 2	Source 2	Student	Primary school participant experiencing AI-monitored classroom environments.
Speaker 1	Source 3	L&D Expert	Specialist in Learning and Development in information-rich environments.
Speaker 1	Source 4	Computer Science Researcher	Expert in metacognition and design principles for "tools for thought".
Speaker 1	Source 5	Technology CEO	Business leader focused on professional AI utility and the "artistry of prompting".
Speaker 1	Source 6	Engineer	Expert in Industry 4.0, digital twins, and mechanical efficiency.
Speaker 1	Source 7	Host	Interviewer for Bloomberg Originals.
Interviewee 1	Source 7	CEO	Head of an AI research organization (OpenAI context).
Speaker 1	Source 8	Industry Expert	Characterizes the 5th Industrial Revolution as a fusion of physical and biological worlds.
Speaker 1	Source 9	Industry Expert	Specialist in "AI Factories" and national-scale intelligence manufacturing.
Speaker 1	Source 10	Host / CIO	Chief Information Officer hosting a discourse on AI in Africa.
Speaker 2	Source 10	Co-host	Co-moderator for regional AI discussions.
Interviewee 1	Source 10	AI Ethics Ambassador	Expert guest and Chief Promoter of AI in Africa; specialist in regional algorithmic bias.
Speaker 1	Source 11	Host	Interviewer discussing Industry 5.0.
Interviewee 1	Source 11	Guest / Expert	Specialist in Industry 5.0 and the "Digital Twin of the Person".
Speaker 1	Source 12	High School Junior	Student providing a generational perspective on automation and technological culture.

Table 1 presents the demographic and professional profile of participants drawn from 12 interview and media sources, reflecting a diverse range of expertise relevant to intelligent machines, artificial intelligence (AI), and the Fifth Industrial Revolution (5IR). The participants comprise academics, AI researchers, technology executives, engineers, learning and development specialists, industry

experts, media hosts, an AI ethics ambassador, and students from both primary and secondary education. This diversity provides multiple perspectives spanning educational practice, neuroscience, computer science, AI governance, industrial innovation, and learner experiences. While experts contribute theoretical, technological, and policy-oriented insights into AI-enabled learning and Industry 5.0, the inclusion of student participants offers firsthand accounts of interacting with intelligent technologies in educational settings. Collectively, the varied backgrounds of the participants strengthen the credibility of the findings by ensuring that the study captures both expert knowledge and authentic learner experiences regarding the future of learning in the era of intelligent machines.

Thematic Analysis

The section presents the analysis of transcripts from the collected data, providing themes and subthemes

Theme 1: Intelligent Machines and Students' Learning Experiences in the Fifth Industrial Revolution

This theme addresses the first purpose of the study by examining how the direct, lived experience of learning changes once intelligent machines become embedded participants in the classroom. Across the sources, the machine is not a passive backdrop but an active presence that measures, reports on, and reshapes what it means to "learn" in real time. Four sub-themes illustrate this shift: the monitoring of cognitive states, the psychological consequences of being monitored, the expansion of experience through immersive technology, and a deeper redefinition of learning itself as a cognitive rather than mechanical activity.

Real-time neuro-monitoring of learning. The clearest illustration of intelligent machines altering the learning experience is the use of EEG-enabled "headbands" that capture students' concentration levels as they occur. Rather than being assessed retrospectively through tests or teacher observation, learners are placed under continuous biometric surveillance, with data relayed to teacher consoles and shared with parent groups "at 10-minute intervals" (Speaker 1, Source 2). This transforms the classroom into a data-generating environment in which attention itself becomes a quantified, trackable variable.

Psychological pressure from continuous monitoring. This visibility is not experience-neutral. Where concentration scores are displayed and shared, low readings translate into real-world consequences, including parental discipline of the child (Interviewee 2, Source 2). The sub-theme highlights that intelligent machines do not simply record learning; they can actively produce stress and anxiety when their outputs are used as a basis for judgment or punishment, raising questions about the emotional cost of embedding surveillance technology in pedagogy.

Immersive access for remote learners. In contrast to the pressure created by monitoring, intelligent machines also expand what students can experience. Virtual reality headsets allow learners in remote or under-resourced areas — the sources cite "a city in Nigeria" as an example — to virtually visit locations such as the International Space Station (Interviewee 1, Source 10). Here, the machine functions as a bridge across geographic and infrastructural inequality, offering experiential learning that would otherwise be inaccessible.

Redefinition of learning as cognitive work. At a more conceptual level, the notion of "Cognitive Efficiency" suggests that intelligent machines are reshaping what counts as valuable learning activity in the first place. Learning is reframed away from "doing and executing" tasks and toward

"exploring and connecting" ideas (Interviewee 1, Source 11). This sub-theme suggests that the influence of intelligent machines is not confined to tools used within lessons; it extends to a philosophical repositioning of what students are expected to be doing when they learn.

Theme 2: Human–AI Collaboration through Augmentation (not Automation)

This theme responds to the second purpose of the study, which distinguishes augmentation — AI extending and supporting human capability — from automation, in which AI simply replaces human effort. The sources converge on the idea that the most valuable forms of AI integration preserve the learner's or worker's agency rather than removing it. The four sub-themes trace this from AI's administrative support role, to a philosophical distinction between assistance and thinking tools, to specific design principles, and finally to AI acting as an extension of the person.

AI as administrative/teaching assistant. The most direct form of augmentation described is AI functioning as a "Teaching Assistant" that manages lesson planning and mundane grading, freeing educators to concentrate on content delivery and individualized instruction (Speaker 1, Source 1). Here, augmentation is understood in labor terms: the machine absorbs repetitive administrative work so that the human retains the higher-value, relational aspects of teaching.

AI as "tool for thought" rather than assistant. A more conceptual distinction is drawn between AI as an "assistant," which risks outsourcing reasoning entirely to the machine, and AI as a "tool for thought," which keeps the human actively reasoning (Speaker 1, Source 4). This sub-theme frames augmentation not merely as a division of labor but as a design orientation: the same technology can either erode or strengthen human cognitive involvement, depending on how it is built and used.

Productive resistance in AI design. Building on this distinction, the design principle of "Productive Resistance" proposes that an augmentation-oriented tool should not simply obey the user but should "challenge the user" (Speaker 1, Source 4). This sub-theme illustrates a concrete mechanism for keeping humans engaged: friction and pushback from the system, rather than frictionless compliance, is treated as a feature that protects human judgment.

Autonomous agents acting on a person's behalf. At the most advanced end of the spectrum, the concept of a "Digital Twin of the Person" describes autonomous AI agents capable of holding conversations and executing tasks on an individual's behalf (Interviewee 1, Source 11). This sub-theme signals a boundary condition for augmentation: as agents take on more independent action, the line between supporting a person and acting as that person becomes harder to maintain, which is directly relevant to how far augmentation can extend before it begins to resemble automation.

Theme 3: Personalized Learning and Student Engagement

Addressing the third purpose of the study, this theme captures how intelligent machines tailor instruction to the individual learner and sustain engagement through responsiveness, real tools already in use, diagnostic precision, and accessibility.

Adaptive, individualized tutoring. AI is described as an "infinitely patient" tutor capable of adjusting its pace and method to the individual learner (Speaker 1, Source 1). This sub-theme establishes the baseline promise of personalization: a form of one-to-one instruction that is difficult to replicate at scale with human teachers alone, because the machine does not tire of repetition or varied explanation.

Adaptive-learning platforms in practice. This promise is grounded in named, real-world tools — "Dream Box" and "Smart Sparrow" — identified as platforms currently used for adaptive learning (Interviewee 1, Source 10). Including this sub-theme moves personalization from an abstract capability to an observable, adopted practice within education systems.

Diagnostic identification of individual cognitive blocks. A more granular form of personalization is illustrated by "The MAA," a mathematics-specific AI that tracks precisely where individual students struggle with algebraic transitions (Interviewee 1, Source 10). This sub-theme demonstrates that personalization can operate at the level of specific cognitive sticking points rather than broad ability levels, allowing intervention that is targeted rather than generic.
Accessibility as a form of engagement. Personalisation is shown to serve equity as well as pace: the translation of text and images to speech is cited as assisting students with learning disabilities (Speaker 1, Source 1). This sub-theme broadens the meaning of "engagement" to include learners who might otherwise be excluded from standard instructional formats, positioning accessibility as a core rather than peripheral benefit of intelligent machines.

Theme 4: Collaborative Intelligence and Critical Thinking
This theme speaks to the fourth purpose of the study, probing whether collaborative intelligence between students and AI systems strengthens or weakens critical thinking. The sub-themes present both a constructive use case and clear risks, alongside a specific skill positioned as the bridge between the two.
Using AI to stress-test one's own reasoning. On the constructive side, students are encouraged to use AI to find "holes" in their own arguments, positioning the machine as a sparring partner for reasoning rather than a replacement for it (Speaker 1, Source 1). This sub-theme demonstrates one concrete way collaborative intelligence can promote, rather than erode, critical thinking.
Risk of homogenized, "hive mind" thinking. Set against this is the risk that outsourced reasoning produces a "hive mind" effect, in which collective creativity decreases as more people converge on AI-generated answers (Speaker 1, Source 4). This sub-theme cautions that collaborative intelligence, if not carefully structured, can flatten the diversity of thought it might otherwise be expected to support.
Erosion of metacognition. Closely related is the concern that over-reliance on AI turns users into "middle managers" of their own thoughts — delegating and approving output rather than generating it (Speaker 1, Source 4). This sub-theme identifies a specific cognitive cost of poorly designed collaboration: the gradual withdrawal of the human from the act of thinking itself.
Prompting as a critical-thinking skill. Finally, mastering the "Artistry in prompting" is framed as equivalent to the skill of asking high-quality questions (Speaker 1, Source 5). This sub-theme reframes prompting not as a technical shortcut but as a genuine critical-thinking competency, suggesting that how a student interrogates an AI system can itself be evidence of — and practice for — rigorous thought.

Theme 5: Shared Decision-Making in AI-Supported Learning Environments
This theme addresses the fifth purpose of the study, concerning how decision-making authority is distributed between humans and machines. The sub-themes move from specific interface-level design principles to broader philosophical and economic reflections of what shared authority looks like in practice.
Keeping the human central to the work. The principle of "Material Engagement" requires that the user remain directly involved in constructing the argument or piece of work, rather than receiving a finished product from the machine (Speaker 1, Source 4). This sub-theme operationalizes shared decision-making as a design constraint: the system is built so that authorship cannot be fully ceded to the AI.

Prompting reflection rather than dictating answers. Complementing this, "Scaffolding Metacognition" has the system prompt the user to reflect on their own thinking process rather than simply supplying a final answer (Speaker 1, Source 4). This sub-theme shows shared decision-making being built into the interaction itself, with the machine acting as a facilitator of human judgment rather than a substitute for it.

Consciousness-centred human–AI problem solving. At a broader level, the Fifth Industrial Revolution is described as placing human consciousness alongside machine capability in solving complex problems (Speaker 1, Source 8). This sub-theme situates shared decision-making within a larger societal narrative, in which human judgment is treated as a necessary, non-substitutable complement to machine intelligence.

Negotiated, outcome-based service models. Shared authority also has an economic dimension: a shift from selling mechanical hardware to charging for service-based outcomes reflects a renegotiated value exchange between human organizations and machine-driven systems (Organization 1, Source 6). This sub-theme extends shared decision-making beyond the classroom, showing how outcome-based arrangements require ongoing human oversight of what a machine-delivered service is actually achieving.

Theme 6: Ethical Challenges in Integrating Intelligent Machines into Education

This final theme responds to the sixth purpose of the study, identifying the ethical risks that accompany the integration of intelligent machines into education. The sub-themes span technical limitations, systemic bias, high-level warnings, and institutional responses.

Limits of data anonymization. A foundational ethical concern is that individual student data collected in a classroom assessment context "cannot be truly anonymized," which raises significant privacy risks (Interviewee 1, Source 2). This sub-theme underscores that ethical safeguards commonly assumed to protect students — such as anonymization — may be structurally inadequate once biometric or behavioral data is involved.

Reliability of biometric measurement. Compounding this concern, EEG readings are described as highly susceptible to "artifacts" — false signals produced by movement or itching rather than genuine changes in attention (Interviewee 1, Source 2). This sub-theme raises a validity issue alongside the privacy one: decisions and consequences may be based on data that does not reliably reflect the student's actual cognitive state.

Regional and racial bias in AI systems. A further ethical challenge concerns fairness across populations: Western-centric training data is said to produce "bias against Africans," leading to the misreading of cultural context in areas such as facial recognition and policing (Interviewee 1, Source 10). This sub-theme highlights that ethical risk is not evenly distributed and that regions underrepresented in training data face compounded disadvantages.

High-profile warnings on unregulated AI. The seriousness of these risks is reinforced by warnings from two high-profile figures regarding the dangers of unregulated AI, cited to underscore the need for oversight (Interviewee 1, Source 10). This sub-theme situates the education-specific ethical concerns within a wider, publicly recognized debate about the risks of insufficiently governed AI systems.

Emergence of dedicated ethics governance roles. Finally, the emergence of new institutional roles such as "AI Ethics Officer" reflects a growing organizational response to these risks (Speaker 1, Source 8). This sub-theme suggests that ethical challenges are beginning to be met not only with individual caution but with formal governance structures dedicated to overseeing AI use.

Summary of the Findings

1. Intelligent machines transform learning through real-time neuro-monitoring, positively enabling immersive access for remote learners via VR (e.g., visiting the "International Space Station") and redefining learning as "exploring and connecting" rather than "doing and executing," but negatively introducing psychological pressure, as continuous EEG "concentration" tracking shared with parents can result in punitive consequences for students.
2. The findings favour augmentation over automation, positively framing AI as a "Teaching Assistant" that handles administrative tasks and as a "tool for thought" that keeps humans reasoning through "Productive Resistance," but the emergence of the "Digital Twin of the Person" signals a negative risk, where autonomous agents acting fully on a person's behalf blur the line between support and replacement.
3. Findings are largely positive, showing AI as an "infinitely patient" tutor, grounded in real platforms like "Dream Box" and "Smart Sparrow," with diagnostic tools like "The MAA" pinpointing specific learning gaps and text-to-speech features supporting students with disabilities, expanding both precision and accessibility in education.
4. The findings reveal a dual effect: positively, students use AI to identify "holes" in their reasoning and develop "Artistry in prompting" as a critical-thinking skill, while negatively, over-reliance risks a "hive mind" effect of homogenised thought and reduces students to "middle managers" of their own thinking, weakening metacognition.
5. Findings emphasise maintaining human authority through design principles like "Material Engagement" and "Scaffolding Metacognition," positively ensuring learners remain central to their own work, while broader shifts toward outcome-based, service-driven economic models illustrate a renegotiated but still human-overseen relationship between people and machines.
6. Findings are predominantly cautionary, highlighting that student data "cannot be truly anonymized," that EEG readings are prone to unreliable "artifacts," and that AI systems exhibit "bias against Africans" due to Western-centric training data, though the emergence of roles like "AI Ethics Officer" reflects a positive institutional response toward governance and accountability.

Discussion

The finding that intelligent machines reshape learning experiences through real-time monitoring, immersive access, and a redefinition of learning as exploration rather than execution aligns with Activity Theory's conceptualization of technology as a mediating tool that transforms how students interact with knowledge and their environment (Vygotsky, 1978; Engeström, 1987). This supports the view that AI technologies extend learning beyond geographic and infrastructural constraints, consistent with literature describing intelligent tutoring systems and learning analytics as mechanisms for personalized, adaptive support (Fortuna et al., 2025; Huang et al., 2025). However, the psychological pressure created by continuous biometric surveillance echoes concerns raised by Wang and Li (2026) regarding the risks of excessive dependence on intelligent systems, suggesting that when mediating tools are poorly regulated by institutional rules, they can produce unintended emotional costs rather than the cognitive and social benefits Activity Theory anticipates from well-structured human–technology mediation.

The finding that AI functions most effectively as an administrative assistant and a "tool for thought" rather than a replacement for human reasoning directly reflects the augmentation–automation paradox described by Raj et al. (2026), which holds that AI's greatest educational value

lies in strengthening human judgment rather than substituting for it. This is consistent with Activity Theory's framing of division of labour, in which intelligent machines absorb computational and administrative tasks while teachers retain relational, ethical, and pedagogical responsibilities (Wang & Li, 2026). The emerging risk associated with autonomous agents acting fully on a person's behalf, however, supports Chan and Tsi's (2024) caution that AI should not substitute for the socially and ethically grounded dimensions of human involvement, indicating that as machine autonomy increases, the collaborative boundary central to augmentation becomes increasingly difficult to sustain.

The predominantly positive findings regarding adaptive tutoring, diagnostic precision, and accessibility support the literature's characterization of personalized learning as one of AI's most established educational applications (Inthanon & Wised, 2024; Gligorea et al., 2023). The presence of named platforms actively used in practice reinforces claims by Fortuna et al. (2025) that adaptive systems generate measurable improvements in individualized instruction and continuous academic support. From an Activity Theory perspective, these tools function effectively as mediating artefacts precisely because they are embedded within specific pedagogical contexts rather than applied generically, corroborating Engeström's (1987) assertion that a tool's educational value depends on how purposefully it is integrated into practice. The accessibility-related finding further aligns with the broader literature's emphasis on AI's potential to expand participation among diverse learner populations.

The dual nature of this finding, positive gains in argument-testing and prompting skill alongside risks of homogenized thinking and diminished metacognition, mirrors an unresolved tension present throughout the literature. While Salido et al. (2025) frame critical thinking as strengthened through exposure to diverse perspectives and inquiry-based engagement, Abubakar et al. (2025) caution that uncritical acceptance of AI outputs can weaken these same competencies. The "middle manager" pattern of delegation identified in the findings closely parallels Tian and Zhang's (2025) and Zhai et al.'s (2024) warnings about superficial engagement arising from overreliance on AI-generated responses. Viewed through Activity Theory, this suggests that collaborative intelligence only fulfills its transformative potential when students remain active subjects negotiating and interpreting machine outputs, rather than passive recipients of automated reasoning.

The finding that design principles such as "Material Engagement" and "Scaffolding Metacognition" preserve learner centrality supports Nizamani et al.'s (2025) argument that human-centered AI requires humans to remain accountable for educational decisions, since intelligent systems lack the contextual and emotional understanding teachers provide. This reinforces Activity Theory's rules and division-of-labour components, which specify that shared authority must be structurally embedded in system design rather than assumed as an automatic outcome of AI deployment. The broader economic shift toward outcome-based service models extends this principle beyond the classroom, suggesting that sustained human oversight, rather than technological capability alone, determines whether shared decision-making translates into genuine collaborative practice.

The predominantly cautionary findings regarding data anonymization, biometric reliability, and regional bias substantiate core concerns raised throughout the ethical literature, particularly Martin and Zimmermann's (2024) warnings about data privacy vulnerabilities and Arora et al.'s (2023) analysis of algorithmic bias reproduction. The identification of bias against underrepresented regions further corroborates Wang et al.'s (2024) observation that unequal access and representation can compound existing educational inequalities rather than resolve them. Within Activity Theory, these findings represent contradictions within the activity system, tensions

between the community's expectations of fairness and the rules governing data use, that Engeström (1987) argues necessitate the reorganisation of practices and policies. The emergence of institutional roles such as an AI Ethics Officer reflects the kind of structural adaptation Memarian and Doleck (2023) recommend, indicating that ethical risks are beginning to be addressed through formal governance rather than left to individual discretion alone.

Recommendation

1. Education authorities should expand virtual reality access in underserved regions to promote equitable experiential learning.
2. AI systems should be built to periodically challenge student responses rather than passively agreeing with them.
3. Institutions should invest in adaptive AI tutoring systems capable of adjusting instruction to individual learning paces.
4. Institutions should design group activities that encourage diverse responses rather than convergence on machine-generated answers.
5. AI tools should be built to prompt students to reflect on their reasoning before offering solutions.
6. Institutions should formally establish dedicated ethics oversight roles to guide responsible AI integration.

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EXPLORING THE INTEGRATION OF TPACK IN STEM EDUCATION: CHALLENGES AND OPPORTUNITIES IN NIGERIA

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Abstract
The Technological Pedagogical Content Knowledge (TPACK) has become a leading framework for understanding the knowledge teachers require to integrate digital tools meaningfully into the teaching and learning process, especially Science, Technology, Engineering, and Mathematics (STEM) instruction. This paper presents a scoping literature review of empirical and conceptual scholarship, published primarily between 2023 and 2026, on the integration of TPACK into STEM education in Nigeria focusing on peer-reviewed studies, policy reports, and comparative Sub-Saharan African evidence, the review examines (i) recent empirical findings on Nigerian teachers' TPACK competencies, (ii) the structural, institutional, and socio-cultural challenges constraining TPACK integration, and (iii) emerging opportunities for strengthening technology-enhanced STEM instruction. Findings indicate that Nigerian teachers generally report reasonably strong discrete technological, pedagogical, and content knowledge, but consistently weaker capacity to integrate these domains into transformative classroom practice. Persistent barriers include unreliable electricity and internet connectivity, under-resourced teacher preparation, weak policy-practice alignment, and pronounced gender disparities in STEM participation. Opportunities include artificial intelligence-informed TPACK models, structured collaborative professional development, government and development-partner connectivity initiatives, and contextually adapted open educational resources. The review concludes that advancing TPACK integration in Nigeria depends less on technology procurement alone than on sustained investment in teacher preparation models attuned to Nigeria's specific infrastructural and socio-cultural realities.
Keywords: **TPACK, STEM education, Nigeria, technology integration, teacher education, digital divide**

Introduction

Science, Technology, Engineering, and Mathematics (STEM) education has become a central pillar of national development strategies worldwide, with governments increasingly recognizing that a technologically literate workforce is essential for economic competitiveness and innovation. In Nigeria, STEM education is positioned as a lever for addressing youth unemployment, diversifying an oil-dependent economy, and building indigenous capacity in science and technology (Okon et al., 2024). Realizing this potential depends heavily on the ability of classroom teachers to translate STEM content into engaging, technology-enhanced instruction, which has placed teachers'

technological competence under increasing scrutiny. The Technological Pedagogical Content Knowledge (TPACK) framework, developed by Mishra and Koehler (2006), offers a widely used lens for understanding the knowledge teachers need to integrate digital tools meaningfully into subject-specific instruction. The TPACK framework is an extension of Shulman's earlier construct of Pedagogical Content Knowledge (PCK), TPACK conceptualizes effective technology-enhanced teaching as arising from the dynamic interaction of three core knowledge domains: technological, pedagogical, and content knowledge, and their four resulting intersections (Koehler & Mishra, 2009). Since its introduction, TPACK has become one of the dominant frameworks guiding research on teacher technology integration across disciplines, especially STEM.

In Nigerian, interest in TPACK has grown substantially over the past years, coinciding with government digitalization initiatives, post-pandemic recovery efforts, and the global proliferation of artificial intelligence (AI) tools in education. A growing body of empirical work has begun to examine how well Nigerian teachers (pre-service and in-service) are equipped to integrate technology into STEM teaching, and what structural, cultural, and policy factors help or hinder this integration (Asemota et al., 2026; Ayo-Vaughan et al., 2023; Olawale et al., 2026). At the same time, Nigeria's STEM education system continues to contend with long-standing challenges, including inconsistent electricity supply, uneven internet penetration, inadequate teacher-training infrastructure, and pronounced gender disparities in STEM participation (Nigerian Communications Commission, 2024; Ojong & Kareem, 2025).

Purpose of the Study

The main purpose of the study is to explore the Integration of TPACK in STEM Education. Specifically, the study will:

(a) assess empirical evidence on Nigerian teachers' TPACK competencies in STEM subjects;
(b) determine the challenges that constrain the effective integration of TPACK into Nigerian STEM classrooms; and
(c) explore opportunities to strengthen TPACK-based STEM instruction in Nigeria.

Theoretical Framework: The TPACK Model

Building on Shulman's (1986) foundational concept of PCK, which blends subject expertise with pedagogical skill, Mishra and Koehler (2006) proposed that effective technology-integrated teaching requires a third, central domain: technological knowledge. The TPACK model therefore comprises three primary knowledge domains: content knowledge, pedagogical knowledge, and technological knowledge, and four knowledge domains formed at their intersections: pedagogical content knowledge, technological content knowledge, technological pedagogical knowledge, and, at the core, technological pedagogical content knowledge itself (Koehler & Mishra, 2009). Rather than treating technology as an add-on to existing teaching practice, the framework positions technology, pedagogy, and content as mutually shaping one another, such that decisions about which digital tool to use cannot be separated from decisions about what is being taught and how it can be taught (Ayo-Vaughan et al., 2023).

TPACK has proven especially relevant to STEM disciplines, where simple digital tools such as graphing calculators and simulation software to advanced platforms such as virtual laboratories and, increasingly, artificial intelligence systems have become integral parts of how scientific and mathematical concepts are represented and explored (Kgosi et al., 2026; Priyanda et al., 2025). A

recent study by Kgosi et al., (2026) has begun to extend the original model of the TPACK to account for AI-driven tools, giving rise to constructs such as "AI-TPACK," which incorporate AI-specific technological knowledge and ethical considerations into the framework. This evolution however, reflects the framework's continued relevance amid rapid technological change, while also raising new questions about how teachers in resource-constrained contexts such as Nigeria can be prepared to use both established and emerging technologies effectively.

STEM Education in Nigeria: Contextual Overview

The Nigeria's National Policy on Education (FGN,2013) identifies science, technology, and vocational education as central to producing the skilled manpower needed for national development, with STEM subjects positioned to equip learners with entrepreneurial, technical, and problem-solving competencies (Okon et al., 2024). Despite this policy emphasis, STEM education in Nigeria continues to be shaped by structural constraints such as chronic underfunding, insufficient laboratory and workshop facilities, large class sizes, and a shortage of qualified STEM teachers have long been documented as barriers to quality STEM delivery in Nigerian schools (Okon et al., 2024). The government and private-sector have had several interventions, including the Computers for All Nigerians Initiative launched with Intel's World Ahead Programme, Lagos State's device-distribution program for public-school pupils and teachers and the Kwara Learn Programme.

Empirical Evidence on TPACK Among Nigerian Teachers

Several studies in Nigeria have assessed teachers' TPACK competencies specifically within STEM subjects. Ayo-Vaughan et al. (2023), surveyed 2,200 secondary school teachers across five local government areas in Delta State using an instrument adapted from Mishra and Koehler's (2006) model, found generally high self-reported TPACK levels across all seven knowledge domains, with the strongest scores in pedagogical knowledge and technological content knowledge, and a comparatively alower score for the fully integrated technological pedagogical content knowledge domain itself. The authors concluded that teachers' foundational pedagogical and content competencies were relatively well established, even as their capacity to synthesize these with technology in fully integrated lesson design remained the least developed component. Olawale et al. (2026), surveyed 711 Universal Basic Education teachers across Lagos, Oyo, and Ogun States, found that although teachers reported above-average self-efficacy in each individual TPACK component, their overall TPACK self-efficacy score was below average, indicating that teachers struggled to combine technological, pedagogical, and content knowledge coherently rather than lacking any one component outright. The study also found that teaching experience, subject specialization, and level of school support were significantly associated with TPACK self-efficacy, while gender differences were not statistically significant among the respondents.

At the pre-service level, Asemota et al. (2026) examined 238 teacher trainees across three universities in north-central Nigeria using a mixed-methods design combining surveys, reflective journals, and focus-group discussions. Their findings indicated that structured TPACK-based coursework significantly predicted trainees' confidence in integrating technology, and that those who engaged in collaborative lesson design and scaffolded field experience developed a stronger grasp of how technology, pedagogy, and content interact. The authors concluded that TPACK must be embedded systematically rather than incidentally within teacher-education curricula if

graduates are to enter classrooms prepared for technology-enhanced STEM instruction. This reflects findings from comparable African contexts such as a study In Tanzania, by Njiku (2024) found that collaborative, video-observed lesson-design activities were effective in developing mathematics teachers' TPACK, again suggesting that structured, collaborative professional development rather than technology exposure alone is central to building integrative capacity. Similarly, in South Africa, Kgosi et al. (2026) found that while teacher educators drew on a wide range of digital tools, artificial intelligence applications, and open educational resources in preparing STEM pre-service teachers, most documented practice clustered at the lower "substitution" and "augmentation" levels of the SAMR model, with comparatively few examples of technology being used to transform STEM tasks fundamentally. These converging findings across Nigeria and comparable Sub-Saharan African settings suggest that policy responses focused solely on device distribution or connectivity are unlikely to be sufficient. Structured, sustained, and collaborative TPACK-focused professional development appears to be the more decisive lever for improving STEM teachers' capacity for integration (Wahono et al., 2025).

Challenges to TPACK Integration in Nigerian STEM Education

Infrastructural and Connectivity Deficits

Despite Nigeria's overall growth in internet penetration, the digital infrastructure underpinning classroom-level technology integration remains highly uneven. Many Nigerian schools, particularly in rural areas, lack reliable electricity, a prerequisite for operating even basic digital devices, let alone laboratory-based STEM technologies (Guardian Nigeria, 2026; Kings Care Universal School, 2024). A baseline study on digital skills conducted by the Nigerian Communications Commission (2024) identified the cost of digital devices and a fragmented energy supply as primary barriers to acquiring digital literacy, particularly outside major urban centres.. The Athena Centre for Policy and Leadership (2026) further observes that national-level connectivity statistics, such as Nigeria's more than 164 million active internet subscriptions, are household- and consumer-level metrics that reveal little about school-level connectivity, device availability, or teachers' pedagogical capacity to make use of available technology

Teacher Preparation and Professional Development Gaps

Even where infrastructure exists, the Nigerian teachers' capacity to translate technological access into integrated STEM pedagogy rather than superficial or substitutive use remains constrained. Asemota et al. (2026) found that pre-service teachers without structured TPACK coursework and scaffolded field experience showed lower confidence in technology integration, while Olawale et al. (2026) similarly linked below-average integrative TPACK self-efficacy among in-service teachers to inconsistent access to school-level support and professional development. This pattern echoes long-recognised challenges in Nigerian teacher education, where technology-related coursework is often theoretical, lacking sustained opportunities for hands-on, subject-specific practice.

Policy-Practice Misalignment

Although Nigeria's National Policy on Education explicitly foregrounds science, technology, and vocational preparation, translating this policy commitment into classroom-level TPACK

development requires curriculum reform, teacher-education redesign, and monitoring mechanisms that remain inconsistently implemented (Okon et al., 2024). The gap between stated policy ambition and on-the-ground implementation capacity, including financing that is not consistently separated for digital learning, and weak monitoring and evaluation systems for tracking school-level technology use has been identified as a central obstacle to translating national digital-education strategies into functional, equitable classroom practice (Athena Centre for Policy and Leadership, 2026).

Gender and Equity Barriers

STEM education in Nigeria continues to be marked by pronounced gender disparities that compound the challenges of TPACK integration. Women constitute only about 22% of STEM graduates in Nigeria annually. Vanguard (2025) and World Economic Forum (2023) attributed entrenched gender stereotypes, socio-cultural expectations, limited access to female role models, and an unequal digital-literacy foundation before students even reach STEM classrooms. A systematic review of STEM equity for girls across Sub-Saharan Africa identified harmful cultural norms, poverty, early marriage, and institutional neglect as compounding barriers that limit girls' sustained participation in STEM (Ojong & Kareem, 2025). The Nigeria's STEM policy has further noted that although gender-equity frameworks exist on paper, budget allocations for gender-responsive STEM programming are frequently insufficient, and few schools implement or monitor gender-responsive STEM initiatives in practice (Edugist, 2025; Leadership Newspaper, 2026). Because girls' pre-existing digital literacy is often lower than that of boys, the burden of building technology-rich, TPACK-supported STEM instruction falls disproportionately on teachers to actively counteract, rather than passively assume, equitable access.

Socio-Economic and Contextual Constraints

Socio-economic conditions shape the feasibility of TPACK integration in Nigerian classrooms. The cost of digital devices remains prohibitive for many public schools and households, and urban-rural disparities in access to digital devices, internet connectivity, and technical support mean that the same TPACK-based instructional strategy may be feasible in a well-resourced urban school and entirely impractical in an under-resourced rural one (Kings Care Universal School, 2024). This contextual variability underscores that TPACK integration in Nigeria cannot be approached as a uniform, one-size-fits-all undertaking, but must instead account for the differentiated realities of Nigerian classrooms.

Opportunities for Advancing TPACK Integration

Artificial Intelligence and Emerging Technologies

The rapid global proliferation of artificial intelligence tools presents both a challenge and an opportunity for TPACK integration in Nigerian STEM education. Emerging “AI-TPACK” scholarship extends the original framework to incorporate AI-specific technological knowledge, encouraging teachers to align AI tools such as intelligent tutoring systems, adaptive practice platforms, and generative AI applications with disciplinary goals rather than adopting them superficially (Kgosi et al., 2026). For Nigeria, where teacher shortages and large class sizes constrain individualized instruction, AI-supported personalization, automated feedback, and virtual laboratory simulations could meaningfully extend STEM teachers' pedagogical reach,

provided that teacher-preparation programs build genuine AI literacy rather than treating AI tools as unexamined add-ons (Kgosi et al., 2026).

Government and Development Partner Initiatives

Programs such as the UNICEF- and Federal Ministry of Education-led Nigeria Learning Passport, and multi-partner school-connectivity initiatives extending internet infrastructure to underserved communities, demonstrate the feasibility of scaling digital-learning access even in resource-constrained settings, though questions remain about whether such pilots can be sustained and expanded to full national coverage (Athena Centre for Policy and Leadership, 2026; UNICEF Nigeria, 2025). Public-private partnerships, such as the Computers for All Nigerians Initiative developed with Intel's World Ahead Programme, similarly illustrate a viable model for expanding affordable device access, particularly if future iterations are deliberately extended beyond urban beneficiaries (Oxford Business Group, 2024).

Structured, TPACK-Based Professional Development

The empirical evidence reviewed above converges on a clear opportunity: structured, sustained, and collaborative professional development focused explicitly on TPACK integration rather than generic ICT training offers the most direct lever for improving Nigerian STEM teachers' capacity. Asemota et al.'s (2026) finding that collaborative lesson design and scaffolded field experience meaningfully strengthened pre-service teachers' technology-integration confidence, and Wahono et al.'s (2025) evidence that structured online professional development programs can advance in-service STEM teachers' TPACK, together suggest a replicable model: embedding TPACK explicitly and iteratively across pre-service curricula and in-service training, rather than treating technology competence as a peripheral add-on to STEM teacher preparation.

Open Educational Resources and Contextualized Digital Tools

Open educational resources present a further opportunity for Nigerian STEM educators to overcome cost and access barriers associated with commercial digital tools and textbooks. Comparative evidence from South Africa suggests that open educational resources, when adapted to reflect local languages, curricula, and classroom realities, can provide fertile ground for content-specific, technology-rich STEM lessons even in low-bandwidth environments (Kgosi et al., 2026). Similarly, mobile-first and offline-capable digital tools designed explicitly for the connectivity and electricity constraints common to many Nigerian schools offer a more context-sensitive pathway to technology integration than approaches modelled on well-resourced, high-bandwidth settings.

Gender-Responsive STEM-Technology Programming

Gender-responsive interventions present an opportunity to address Nigeria's STEM gender gap in tandem with TPACK-based reform. Programs that pair digital-literacy training for girls with mentorship from women already working in STEM and technology fields have shown promise in raising interest and confidence among Nigerian girls, suggesting that TPACK-based STEM instruction reform efforts could be deliberately paired with gender-responsive outreach to maximize their equity impact (Ojong & Kareem, 2025; Vanguard News, 2025).

Discussion

The literature reviewed suggests that the central challenge facing TPACK integration in Nigerian STEM education is not simply an absence of technology, but a persistent gap between discrete

technological, pedagogical, and content competencies and teachers' capacity to synthesize them into coherent, transformative classroom practice. This gap recurs across contexts as different as Delta State secondary schools (Ayo-Vaughan et al., 2023), Southwest Nigeria's basic education system (Olawale et al., 2026), and comparable settings in Tanzania (Njiku, 2024) and South Africa (Kgosi et al., 2026), suggesting it may be a structural feature of how TPACK develops under resource-constrained conditions rather than an isolated Nigerian phenomenon. Nigeria's specific infrastructural and socio-economic conditions such as unreliable electricity, uneven internet access, the cost of devices, and pronounced gender disparities mean that solutions imported wholesale from better-resourced contexts are unlikely to transfer directly. What emerges instead is a case for what Kgosi et al. (2026) term "adaptive digital competence": preparing teachers not only to use sophisticated tools where they are available, but to innovate meaningfully with limited technologies in under-resourced settings. For Nigeria, this suggests that TPACK-based teacher education should explicitly train teachers to design STEM lessons that function within low-bandwidth, intermittent-electricity, and shared-device realities, rather than assuming ideal conditions. The consistency with which structured, collaborative, and sustained professional development emerges as the more decisive lever for TPACK development also carries direct implications for Nigerian teacher-education policy. Investments concentrated solely on hardware and connectivity, while necessary, appear insufficient without parallel investment in the pedagogical scaffolding, mentorship, and collaborative design opportunities through which teachers actually learn to integrate technology meaningfully into STEM instruction.

Recommendations

Based on this review, several recommendations emerge for policymakers, teacher-education institutions, and school leaders in Nigeria. Teacher-education curricula, both pre-service and in-service, should embed TPACK systematically across STEM methods courses, rather than confining technology training to standalone ICT modules disconnected from subject-specific pedagogy (Asemota et al., 2026). Professional development programs should prioritise collaborative, sustained formats such as lesson-design workshops, peer mentoring, and video-based reflective practice instead of one-off training sessions, given consistent evidence that such formats build integrative TPACK more effectively than technology exposure alone (Njiku, 2024; Wahono et al., 2025). Also, infrastructure investment should be paired explicitly with "adaptive digital competence" training, preparing teachers to design effective STEM instruction under real Nigerian conditions like intermittent electricity, shared devices, and variable connectivity rather than assuming ideal, fully resourced classrooms (Kgosi et al., 2026). Policymakers should strengthen the ring-fencing of financing for school-level digital-learning infrastructure and establish robust monitoring and evaluation systems capable of tracking classroom-level, rather than merely national-level, connectivity, device availability, and teacher TPACK development (Athena Centre for Policy and Leadership, 2026). Likewise, gender-responsive programming should be deliberately integrated into STEM-technology reform efforts, including targeted digital-literacy training, mentorship, and visible female role models in STEM and technology fields, to ensure that TPACK-based reforms do not inadvertently widen existing gender gaps in STEM participation (Ojong & Kareem, 2025). Finally, given the rapid emergence of AI-based educational tools, teacher-education programs should begin building foundational AI literacy into STEM teacher preparation now, framed within an AI-TPACK lens that emphasizes critical, ethical, and pedagogically grounded use rather than uncritical adoption (Kgosi et al., 2026).

Conclusion

This review has examined recent literature on the integration of the TPACK framework into STEM education in Nigeria, drawing on empirical studies, policy analyses, and comparative African evidence. Nigerian teachers, across multiple studies and contexts, appear to possess reasonably solid discrete knowledge of technology, pedagogy, and content, yet consistently show comparatively weaker capacity to integrate these domains into transformative STEM instruction Chronic challenges like the unreliable electricity, uneven connectivity, under-resourced teacher education, and entrenched gender disparities continue to constrain what TPACK-based reform can achieve in the short term. At the same time, emerging opportunities, from AI-TPACK models to government-development partner connectivity programs, structured collaborative professional development, and open educational resources, suggest concrete, evidence-based pathways forward. Realizing the potential of TPACK in Nigerian STEM classrooms will likely depend less on technology procurement alone than on sustained investment in teacher-preparation models attuned to Nigeria's specific infrastructural and socio-cultural realities. Future research should track how these dynamics evolve as AI tools become more widely accessible and as ongoing government digitalization initiatives mature.

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BEYOND ACCESS: THE CASE FOR INTEGRATED EVALUATION OF MOBILE LEARNING APPLICATIONS IN SECONDARY SCHOOL BIOLOGY IN NIGERIA

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Abstract

Mobile learning is increasingly promoted as a remedy for the constraints facing Nigerian secondary education, among them overcrowded classrooms, scarce instructional materials and limited laboratory provision. This paper argues that the prevailing basis for adopting mobile learning applications in secondary school Biology is unsound. Adoption decisions are being taken on the strength of device availability, novelty and vendor claims, rather than on demonstrated instructional effectiveness. The paper advances four propositions. First, the evidence that mobile learning improves achievement is substantial but conditional, and the conditions are routinely omitted when the evidence is cited in support of procurement. Second, Biology presents an unusually strong prima facie case for mobile learning, since the concepts with which candidates most consistently struggle in the West African Senior School Certificate Examination are precisely those that are abstract, microscopic or dynamic, and therefore amenable to visualisation. Third, the dominant evaluation practice, which examines usability, acceptance, engagement or achievement in isolation, produces findings that cannot support an adoption decision and may actively mislead it. Fourth, in the Nigerian implementation context the determinants of success lie less in the application than in connectivity, data cost, device access and teacher capacity. The paper concludes that no mobile learning application should be adopted for Biology instruction in Nigerian secondary schools without integrated evaluation across usability, perceived usefulness, engagement and measured achievement, and sets out what such evaluation should require of policymakers, school administrators, developers and researchers.

Keywords: mobile learning, Biology education, secondary education, technology adoption, educational evaluation, Nigeria

Introduction

The argument for mobile learning in Nigerian secondary education is easy to make and is made often. Classrooms are overcrowded, instructional materials are scarce, laboratory provision is uneven, and the physical infrastructure of many schools constrains what teaching can accomplish. Against this, mobile devices are increasingly available, they are portable, they are already in the hands of many learners and their families, and they offer flexibility in time and place that conventional provision cannot match (Crompton & Burke, 2020; Haleem et al., 2022). The

inference is tempting and is frequently drawn, namely that where conventional provision fails, mobile provision should be introduced. This paper does not dispute the premises. It disputes the inference. The availability of technology is not evidence that technology will teach, and the failure of an existing arrangement is not evidence that a proposed replacement will succeed. Between the two lies a question of instructional effectiveness that is empirical, that is specific to subject and context, and that is at present being answered by assumption rather than by evidence in most Nigerian adoption decisions. The consequences of getting this wrong are not trivial. Schools that invest in applications which do not improve learning have spent scarce resources without return and have done so in a policy environment where the same funds might have supported laboratory consumables, teacher development or textbook provision. Families that purchase devices and data on the understanding that this will improve their children's results bear a real cost. And a sector that adopts educational technology on weak evidence and then observes no improvement is likely to conclude that the technology does not work, when the accurate conclusion is that this implementation of it did not. The position advanced here is therefore a conditional endorsement rather than either advocacy or scepticism. Mobile learning applications have a demonstrable place in secondary school Biology instruction in Nigeria, but the case for any particular application must be established before adoption and must be established across four dimensions simultaneously rather than one at a time.

Statement of Position

This paper takes the position that no mobile learning application should be adopted for Biology instruction in Nigerian secondary schools based on access, novelty or general evidence about mobile learning as a category. Adoption should be conditional on integrated evaluation of the specific application across four dimensions, namely usability, perceived usefulness, student engagement and measured academic achievement, conducted in conditions resembling those in which the application will actually be used. Proposition one holds that the evidence base for mobile learning is strong but conditional, and that the conditions are systematically omitted when the evidence is invoked in support of adoption. Proposition two holds that Biology presents a stronger prima facie case for mobile learning than most school subjects, and that this case is specific enough to be tested rather than assumed. Proposition three holds that single-dimension evaluation, which is the dominant practice in the literature and institutional decision-making alike, cannot support an adoption decision and may mislead it. Proposition four holds that in the Nigerian context the principal determinants of whether a mobile learning application succeeds lie outside the application itself, in connectivity, data cost, device access and teacher capacity, and that evaluation which ignores these conditions is not evaluation of anything a school will experience. The quantitative case for mobile learning is genuinely substantial. Talan (2020) synthesised 104 experimental studies involving 7,568 participants and reported a mean effect size of 0.85, which by conventional standards is large. Sung, Chang and Liu (2016) found significant positive effects of mobile-device-supported learning across a range of subjects. More recent syntheses report the same direction of effect (Pedraja-Rejas et al., 2024; Garzón et al., 2025). Taken at face value, these

findings appear to settle the question. They do not, for three reasons that are visible within the same literature. The first is that meta-analytic effect sizes in educational technology are known to be sensitive to novelty. When an unfamiliar tool is introduced for a short period, learners attend to it more closely than they attend to routine instruction, and the resulting gain reflects attention as much as instructional design. Studies of longer duration typically report smaller effects, which means that an effect size derived largely from short interventions is a poor guide to what a school should expect from sustained use across a school year.

The second reason is that these syntheses aggregate across subjects, age groups, devices, durations and instructional designs. An effect size of 0.85 describes a distribution, not a prediction. It tells a Nigerian school nothing about whether a particular Biology application, used by Senior Secondary Two students in a particular classroom for a particular topic, will produce measurable gain. To treat a category-level finding as a warrant for an instance-level decision is a straightforward error of inference, and it is the error most committed in adoption discussions. The third and most important reason is that literature itself states the condition. Crompton and Burke (2020) find that pedagogical outcomes depend on how technology is used rather than on its presence, and Pedraja-Rejas et al. (2024) similarly qualify positive findings by reference to design quality. The reviewed evidence supports a conditional claim, namely that well-designed mobile learning aligned to curriculum objectives improves outcomes. It does not support the unconditional claim that mobile learning improves outcomes. The conditional is the finding; dropping it is not summarising the evidence but misreporting it.

The practical implication is direct. A school or ministry citing meta-analytic evidence in support of adopting a specific application has not made an argument for that application. It has made an argument that applications of this general kind can work when well designed, which leaves entirely open the question of whether the one under consideration is well designed.

Biology Presents a Specific and Testable Case

Not every school subject stands to gain equally from mobile delivery, and the case for Biology is stronger than most. It rests on a correspondence between the properties of the subject matter and the affordances of the medium, and that correspondence is specific enough to be tested rather than merely asserted. The Biology curriculum is concept-driven and requires learners to integrate ideas that are abstract, microscopic or dynamic. Cellular processes, digestion, genetics and ecological systems cannot be directly observed by a Senior Secondary Two student in a classroom without laboratory access, and they are poorly served by verbal explanation and static board diagrams alone. Reports of the West African Examinations Council identify the digestive system, human blood, cells, ecological niche and gametes among the concepts with which candidates most consistently struggle (WAEC, 2021, 2023). These are not randomly distributed across the syllabus. They are concentrated precisely among the topics that are hardest to represent by conventional means.

The Cognitive Theory of Multimedia Learning offers an account of why visual and animated representation might address this. Learners process verbal and visual information through related but capacity-limited channels, and appropriate combinations of words with diagrams and animations can support understanding where verbal explanation alone would not (Mayer, 2024; Cavanagh & Kiersch, 2023). A process such as peristalsis or the movement of blood through the heart is dynamic, and a static representation requires the learner to supply the motion mentally, which is an additional cognitive demand that an animation removes. There is preliminary Nigerian evidence consistent with this. Eno, Uko and Utibe (2023) used a quasi-experimental design with 150 students in Akwa Ibom State and found that those taught nutrition concepts with mobile phones and projectors outperformed those taught by an expository approach. Alsalhi (2025) reported significantly better science scores among learners using mobile technology. The argument must be stated carefully, however, because the same theory that supports the case also constrains it. The Cognitive Theory of Multimedia Learning predicts benefit from well-designed multimedia and harm from poorly designed multimedia, since excessive or decorative visual material increases cognitive load rather than reducing it (Mayer, 2024). An application that presents an animation of the digestive system with accompanying narration, on-screen text and background music is likely to impede comprehension rather than assist it. The theoretical case for Biology is therefore not a case for mobile applications in Biology generally. It is a case for evaluating whether a particular application's multimedia design conforms to the principles that make multimedia effective, which is an empirical question about that application and not a settled matter of principle.

Single-Dimension Evaluation Cannot Support an Adoption Decision

The third proposition concerns how mobile learning applications are currently evaluated, and it is the proposition on which this paper places the greatest weight. The dominant evaluation practice examines one dimension at a time. A substantial body of work applies the Technology Acceptance Model and establishes that perceived ease of use influences perceived usefulness and behavioural intention (Davis, 1989; Saleh et al., 2022; He et al., 2023; Balaman & Baş, 2023). A second body of work examines engagement and finds that interactive mobile environments increase participation, interest and motivation (Tlili et al., 2023). A third examines achievement and reports learning gains (Talan, 2020; Sung et al., 2016; Eno et al., 2023). Each literature is internally coherent. The difficulty is that they rarely intersect. This matters because the four dimensions can dissociate, and the ways in which they dissociate are exactly the ways that would mislead a decision-maker relying on one of them. Table 1 sets out the principal failure modes.

Table 1

Failure Modes Concealed by Single-Dimension Evaluation

Evaluation dimension used alone	Favourable result obtained	Failure the result conceals
Usability	Students navigate the application easily and report satisfaction with the interface	An application may be effortless to use and instructionally empty, since ease of navigation says nothing about whether the content is aligned to the curriculum
Perceived usefulness	Students believe the application helps them learn Biology	Learner belief about learning is an unreliable proxy for learning, and fluent presentation can raise confidence without raising attainment
Engagement	Students participate actively, sustain attention and report high motivation	Engagement may attach to the interactive form rather than to the biological content, and short-term novelty is difficult to distinguish from durable interest
Academic achievement	Post-test scores exceed pre-test scores in the experimental group	Without usability and engagement data the source of the gain is unidentifiable, so the finding cannot be transferred to another school or another topic

The last of these deserves particular emphasis, since achievement is the dimension decision-makers most readily accept as decisive. A pre-test to post-test gain establishes that something worked. It does not establish what worked and therefore does not establish what must be preserved when the application is deployed elsewhere. If the gain arose because a well-designed animation resolved a specific conceptual difficulty, the finding will transfer to other schools teaching that topic. If it arose because students in experimental conditions received more instructional time, or more teacher attention, or the stimulus of an unfamiliar activity, it will not. Achievement data alone cannot distinguish these, and an adoption decision made on achievement data alone is therefore made without knowing whether the result will recur. The converse case is equally consequential and is more common in practice. Applications are frequently adopted on the strength of favourable usability and acceptance data, since these are inexpensive to collect and reliably positive. Such data establishes that students find the application agreeable. They establish nothing whatever about whether students learn Biology from it. An evaluation design that stops at acceptance has measured the conditions for learning and has not measured learning. The four dimensions are related in a defensible sequence. Usability conditions engagement, since an application that is difficult to navigate will not sustain participation. Engagement conditions achievement, since content that is not attended to is not learned. Perceived usefulness conditions continued voluntary use, which matters for any application intended to support learning outside lesson time. Achievement is the outcome that justifies the whole arrangement. Because the dimensions form a chain, a break at any

point defeats the purpose, and a design that observes only one link cannot report on the integrity of the chain.

Implementation Conditions Determine Outcomes

The fourth proposition is that in the Nigerian context the principal determinants of success lie outside the application. This is not a peripheral qualification but a central element of the position. Sustained mobile learning requires suitable devices, internet connectivity, compatible operating systems, manageable data demands and sufficient digital literacy on the part of learners (Martin et al., 2022; Al-Rahmi et al., 2022). Each of these is variable across Nigerian schools and households, and several are variable within a single classroom. Okunade, Daramola and Jegede (2023) found that the use of available information and communication technology resources in Biology teaching remained limited in Ekiti State because of infrastructural and skills-related constraints, which is to say that resources which existed were not used. This is the characteristic Nigerian implementation failure, and it is not a failure of the technology. Three consequences follow for evaluation design. The first is that any evaluation conducted in a school with reliable connectivity, functional devices and a confident teacher has evaluated the application under conditions that most schools do not enjoy, and its results will overstate what those schools should expect. A study that selects experimental schools on the basis of functional facilities and control schools that lack them has, in addition, confounded the intervention with the infrastructure, and cannot separate the effect of the application from the effect of the environment in which it was used. The second is that offline functionality is not a convenience feature in this context but a condition of equity. An application requiring continuous connectivity converts a pedagogical intervention into a recurrent household expense, and the learners excluded by that expense will disproportionately be those whose schools are least well provided for by conventional means. The technology would then widen the gap it was introduced to narrow. The third is that teacher capacity is part of the intervention rather than a precondition of it. Mobile learning represents an integration of technology and pedagogy rather than the presence of a device (Crompton & Burke, 2020), and integration is performed by teachers. An application deployed to teachers who have not been prepared to use it is a different intervention from the same application deployed to teachers who have. Evaluations that do not document teacher preparation have not fully specified what was evaluated.

Objections Considered

That Evidence Is Already Sufficient

It may be objected that with meta-analytic support of this magnitude, further evaluation of individual applications is an unnecessary delay, and that the cost of postponing adoption exceeds the cost of occasional misjudgement. The objection has force where the intervention is cheap and the downside is small, but neither condition holds here. Adoption commits school budgets, teacher preparation time and household expenditure on devices and data, and it displaces alternative uses of the same resources. More importantly, the objection depends on the very inference this paper

disputes, namely that category-level evidence licenses instance-level decisions. Evidence that mobile learning applications can work is not evidence that this one does.

That Integrated Evaluation Is Impractical

A second objection holds that evaluation across four dimensions is beyond the capacity of schools and ministries, which lack research expertise and time. This is a serious objection, and the response is a matter of degree rather than principle. Full experimental evaluation of every candidate application is indeed impractical at school level. What is practical, and what this paper proposes, is that evaluation be conducted once per application by competent researchers and that its findings be made available to schools, in the manner of a curriculum approval process. The burden falls on the evaluating body rather than on each adopting school. The alternative, in which every school forms its own impression from vendor material, is not a lighter burden but an unexamined one.

That Mobile Devices Distract More Than They Teach

A third objection comes from the opposite direction and holds that mobile devices in schools introduce distraction, that learner-related risks including digital distraction are documented in the same literature (Al-Rahmi et al., 2022; Pedraja-Rejas et al., 2024), and that the prudent course is prohibition. This paper accepts the documented risk and rejects the inference. Distraction is a design and management variable rather than an intrinsic property of the medium, and an application with a constrained interface used within a structured lesson presents a different risk profile from unrestricted device access. The objection is nonetheless useful, because it identifies a further dimension that integrated evaluation should capture, namely whether observed engagement attaches to the biological content or to the device.

That Infrastructure Should Precede Evaluation

A fourth objection holds that in a context where connectivity and devices are unevenly distributed, evaluating applications is premature, and that investment should first address infrastructure. The sequencing is appealing but impractical, since infrastructure development in Nigerian education has proceeded over decades and shows no prospect of completion that would justify suspending pedagogical work until then. The more defensible course is to evaluate applications under realistic rather than optimal conditions, so that the evidence generated is applicable to the schools that exist rather than to schools that may exist later. This is an argument for a particular kind of evaluation, not against evaluation.

What Follows From This Position

The position advanced here carries specific obligations for each group with a decision to make. These are set out in Table 2 and elaborated below.

Table 2

Obligations Arising from the Position, by Stakeholder Group

Stakeholder	Obligation
Policymakers and examination bodies	Establish an approval process for educational applications comparable to textbook approval, requiring evidence across the four dimensions before an application may be recommended for school use
School administrators	Decline adoption on the basis of vendor demonstration, usability trial or acceptance survey alone, and require evidence of measured achievement gain in comparable conditions
Biology teachers	Treat the application as a supplement to instruction targeted at identified conceptual difficulties rather than as a substitute for teaching, and monitor whether engagement attaches to content or to novelty
Application developers	Align content explicitly to the senior secondary Biology syllabus, design multimedia in accordance with established principles of multimedia learning, and provide offline functionality as a condition of equitable access
Researchers	Design evaluations that measure usability, perceived usefulness, engagement and achievement within a single study, in conditions resembling ordinary rather than favourable school environments

For policymakers, the central recommendation is procedural. Nigeria already operates approval processes for instructional materials, and the case for extending an equivalent process to educational applications is straightforward, since an application that mediates the teaching of a syllabus topic performs the function of a textbook and should meet a comparable standard of scrutiny. The criteria should include curriculum alignment, multimedia design quality, offline capability and evidence of achievement gain. For school administrators, the recommendation is a matter of what evidence to require before committing funds. Vendor demonstrations establish that an application exists and functions. Usability trials establish that students can operate it. Neither establishes that students learn Biology from it, and administrators should ask specifically for evidence of measured achievement gain in schools resembling their own.

For teachers, the recommendation concerns instructional positioning. The strongest case for mobile learning in Biology rests on specific conceptual difficulties in specific topics, which implies targeted rather than general use. An application deployed against the digestive system, cellular structure or ecological relationships, where the representational advantage is real, is being used where the evidence supports it. The same application deployed as a general substitute for instruction is not. For developers, the recommendation is that curriculum alignment and multimedia design discipline are not refinement but the conditions on which the educational claim rests. An application whose content does not map onto the syllabus cannot improve syllabus attainment, and one whose multimedia design increases cognitive load will impede the comprehension it was built to support. For researchers, the recommendation is the one on which

the others depend. The gap identified in literature is not a gap in the number of studies but in their architecture. Studies applying the Technology Acceptance Model establish the importance of perceived usefulness and ease of use without connecting these perceptions to attainment, and studies of engagement seldom incorporate usability and usefulness into the same design (Eno et al., 2023; Balaman & Baş, 2023). What is required is not more single-variable studies but studies that observe the chain from usability through engagement to achievement within one design, so that where an application succeeds it is possible to say why, and where it fails it is possible to say where the chain broke.

Conclusion

Mobile learning has a defensible place in the teaching of Biology in Nigerian secondary schools. The subject matter is unusually well suited to the medium, the conceptual difficulties documented in examination reports are concentrated among topics that benefit most from visualisation, and the available evidence points consistently in a favourable direction. None of this establishes that any application will teach Biology to any particular cohort of learners. The distinction between those two claims is the substance of this paper. Nigerian schools are currently being invited to act on the first as though it were the second, and the invitation is being accepted in a policy environment that has no mechanism for distinguishing an application that improves learning from one that merely appears to. The remedy is neither uncritical adoption nor refusal, but the establishment of an evidential standard that adoption must meet. That standard should require evidence across usability, perceived usefulness, engagement and measured achievement, gathered in conditions resembling those in which the application will be used, and it should be met before adoption rather than discovered afterwards. Until such a standard is in place, decisions about educational technology in Nigerian secondary schools will continue to be made on the basis of what is available rather than what works, and the resources committed to them will continue to be committed in hope rather than in knowledge.

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FROM AUTOMATION TO AUGMENTATION: HUMAN–AI CO-CREATION IN EDUCATIONAL MEDIA PRODUCTION IN THE AI ERA

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Abstract

The emergence of generative AI tools has introduced new possibilities for automating several of these processes, but it has also generated concerns about accuracy, academic integrity, creativity, bias, copyright, data privacy, overdependence and the erosion of professional judgement. This paper examines the transition from automation to augmentation through the lens of human–AI co-creation in educational media production. Drawing on recent literature and emerging evidence from Nigerian tertiary education, the paper argues that the most educationally productive application of AI is not the replacement of human media producers but the augmentation of their creative, pedagogical and professional capacities. The paper conceptualises human–AI co-creation as a collaborative process in which humans establish educational purposes, contextual requirements and quality standards while AI supports ideation, content generation, multimodal production, adaptation, personalisation and iterative refinement. The paper proposes a Human–AI Co-Creation Framework consisting of five interconnected stages: human conception, AI-assisted ideation, collaborative production, human validation and reflective evaluation. The paper concludes that sustainable AI integration in educational media production requires a shift from an automation-centred mindset to an augmentation-centred model grounded in human agency, pedagogical purpose, contextual relevance, ethical responsibility and continuous professional development.

Keywords: artificial intelligence, generative AI, human–AI co-creation, educational media, AI augmentation, instructional design, higher education, Nigeria

Introduction

Educational media have historically played an important role in translating pedagogical ideas into accessible learning experiences. Textbooks, diagrams, photographs, radio programmes, television programmes, instructional videos, animations, presentations, simulations and interactive digital resources have all been used to communicate knowledge and support learning. However, the production of such materials can be labour-intensive. The emergence of AI-enabled production tools potentially changes this workflow by allowing some of these activities to be performed more quickly or with fewer technical resources.

The growing capacity of AI has therefore stimulated an important question: Should AI be used primarily to automate educational media production, or should it be used to augment the capabilities of the humans who produce educational media?

Conceptualising Human–AI Co-Creation in Education

Human–AI co-creation refers to a process in which human beings and artificial intelligence systems contribute complementary capabilities to the development of a product, service, idea or solution. Within education, co-creation involves teachers, learners, instructional designers, educational technologists or media professionals working with AI systems to generate, modify, evaluate or improve educational resources. The concept differs from conventional automation. In a fully automated model, humans define a task and a machine executes it with limited human intervention. For example, an institution might instruct an AI system to generate an entire instructional video from a topic and publish the resulting product without substantive human review. Such a process may increase production speed, but it also transfers substantial responsibility to a system that may not understand the educational, cultural or ethical context surrounding the material.

Co-creation involves a different relationship. Humans establish the purpose, provide contextual knowledge, formulate requirements, evaluate AI-generated outputs and make final decisions. AI contributes computational capabilities such as rapid information processing, pattern generation, language generation, multimodal transformation and iterative production. The relationship is therefore collaborative rather than substitutive.This perspective is consistent with emerging scholarship on teacher agency in the age of generative AI. Frøsig and Romero (2024) argue that GenAI can support teachers in learning design and idea generation while simultaneously creating risks to professional agency if teachers lose their capacity to influence decisions.

Human–AI co-creation can consequently be understood through three complementary principles. First, humans determine educational purpose. AI does not independently determine what learners should know, why they should learn it or which educational values should guide instruction. Second, AI expands production capability. It can help humans generate alternatives, create prototypes, transform content across media formats and accelerate repetitive tasks. Third, humans retain evaluative responsibility. AI-generated materials must be examined for accuracy, relevance, bias, accessibility, cultural appropriateness and pedagogical suitability. This understanding is particularly important because AI-generated content can appear convincing even when it is inaccurate. Large language models, for instance, can produce plausible but false statements, while image-generation systems may reproduce stereotypes or generate culturally inappropriate representations. Consequently, fluency should not be confused with accuracy, and production efficiency should not be confused with educational quality.

From Automation to Augmentation: The Changing Educational Media Landscape

Earlier technologies largely functioned as tools operated by humans. AI increasingly functions as a system that can respond to human instructions and produce content. These capabilities create significant opportunities for educational institutions, particularly where human and financial resources are constrained. AI may reduce some of the costs associated with producing high-quality instructional materials and allow educators to develop multiple versions of the same resource for different learner groups. However, the movement towards automation also introduces the danger of reducing educational media production to a technical process. Educational content cannot be evaluated solely by how quickly it is produced. The central question is whether it supports learning.

Generative AI and Educational Media Production

Generative AI has expanded the scope of what can be produced through natural-language interaction. Text-generation systems can support scriptwriting, lesson explanations and learning activities. Image-generation systems can produce illustrations and conceptual visualisations. Speech-generation systems can create narration. Video-generation systems can assist with animated or synthetic video content. AI-based editing tools can support captioning, translation, transcription, summarisation and media enhancement.

Human–AI Co-Creation Across the Educational Media Production Process

Human–AI co-creation can be conceptualised as a cyclical production process rather than a single interaction with an AI tool.

Stage One: Human Conception

The process begins with the human educator, instructional designer or media professional identifying the learning problem.

Questions at this stage include:

- Who are the learners?
- What should they learn?
- What prior knowledge do they possess?
- What learning difficulty is being addressed?
- What media format is appropriate?
- What cultural and linguistic considerations are relevant?
- What evidence will demonstrate learning?

AI should not replace this stage because the answers depend heavily on pedagogical and contextual knowledge.

Stage Two: AI-Assisted Ideation

Once the educational purpose has been established, AI can be introduced as an ideation partner. The educator may ask AI to generate alternative explanations, examples and analogies, storyboards, visual concepts, discussion questions, scenarios, possible scripts, quiz items, activity ideas and alternative media formats. The human then evaluates these possibilities. This stage transforms AI from an answer-generating machine into a brainstorming partner.

Stage Three: Collaborative Production

In this stage, humans and AI jointly develop the educational media. The AI may generate a draft while the human provides instructions, corrections and contextual information. For example, an educator may prompt an AI system to develop a five-minute instructional video script for first-year Nigerian undergraduates. The first output may be generic. The educator can then provide additional instructions: use Nigerian examples, avoid unnecessary jargon, align the explanation with a specified learning outcome and include two formative questions.

The resulting interaction becomes iterative.

Human → AI → Human → AI → Human.

This iterative process distinguishes co-creation from simple automation.

Stage Four: Human Validation and Refinement

This is arguably the most important stage. Every AI-generated educational resource should undergo human validation. Validation should examine factual accuracy, pedagogical alignment, cultural relevance, linguistic appropriateness, accessibility, ethical implications, copyright and intellectual-property. The educator or media professional remains accountable for the final product even when AI has contributed substantially to its production.

Stage Five: Reflective Evaluation

The final stage involves evaluating how the media performs in actual educational practice. Learner feedback, assessment results, engagement data and teacher observations can inform subsequent revisions.

This makes co-creation cyclical.

Design → AI assistance → production → human validation → implementation → evaluation → redesign.

AI can therefore become part of a continuous improvement process rather than merely a shortcut for content production.

Pedagogical Opportunities of Human–AI Co-Creation

Human–AI co-creation offers several pedagogical opportunities.

First, it can increase production efficiency. Educators who previously required considerable time to produce supporting materials may now develop initial drafts more quickly. Second, it can encourage creative experimentation. Because AI can generate several possibilities rapidly, educators can explore alternative ways of presenting a concept before selecting the most appropriate approach.

Challenges and Ethical Considerations

Despite its potential, human–AI co-creation introduces significant challenges.

Accuracy and Hallucination

Generative AI systems may generate false or misleading information. The problem becomes particularly serious when AI-generated educational materials are presented to students as authoritative knowledge. Human verification is therefore essential.

Academic Integrity

AI-generated content can facilitate plagiarism, contract cheating and the submission of machine-generated work as original student work. Nigerian scholars have identified academic integrity as one of the major concerns surrounding GenAI in higher education (Peters & Olojede, 2025). (journals.abuad.edu.ng). Others include overdependence and cognitive offloading, bias and cultural representation, copyright and intellectual property, data privacy, infrastructure and digital inequality.

A Proposed Human–AI Co-Creation Framework for Educational Media Production

Based on the literature and arguments developed in this paper, a Human–AI Co-Creation Framework is proposed.

Stage 1: Human Conception

The educator identifies learning objectives, learner characteristics, instructional problem, content requirements, cultural context, accessibility requirements and desired media format.

Human responsibility: Purpose and pedagogical direction.

Stage 2: AI-Assisted Ideation

AI is used to generate ideas, examples, scripts, storyboards, visual concepts, alternative explanations, activities and media possibilities.

AI contribution: Creative expansion and rapid prototyping.

Stage 3: Human–AI Production

Humans and AI iteratively develop the educational resource.

Human contribution: Context, judgement, pedagogical knowledge and creative direction.

AI contribution: Generation, transformation, adaptation and production assistance.

Stage 4: Human Validation

The human team evaluates the output for accuracy, relevance, bias, cultural appropriateness, accessibility, ethics, copyright, pedagogical alignment and technical quality.

Human responsibility: Quality assurance and accountability.

Stage 5: Reflective Evaluation

The resource is implemented and evaluated using learner feedback, assessment evidence, engagement information, teacher observations and accessibility feedback.

The findings inform another production cycle.

Outcome: Continuous improvement.

The framework can therefore be represented conceptually as:

Human purpose → AI ideation → Human–AI production → Human validation → Educational implementation → Evaluation → Refinement

The framework deliberately places **human purpose at the beginning and human validation before implementation**. AI operates between these stages as an augmentation mechanism.

Implications for Educational Stakeholders

Implications for Teachers

Teachers should develop AI literacy alongside existing pedagogical and disciplinary knowledge. AI literacy should involve more than knowing how to write prompts. Teachers should understand how AI systems generate outputs, recognise limitations, identify hallucinations, evaluate sources and make ethical decisions about AI use. The role of the teacher is therefore likely to shift from being primarily a transmitter of information to being a designer, curator, evaluator and facilitator of AI-supported learning experiences.

Implications for Instructional Designers

Instructional designers may become increasingly important in AI-enabled educational environments because they can ensure that technological capabilities remain connected to learning theory and instructional objectives. Rather than designing resources entirely from scratch, instructional designers may increasingly design human–AI workflows.

Implications for Educational Technologists

Educational technologists will need to move beyond technical implementation towards AI governance, training, evaluation and institutional strategy. They can help institutions determine which AI tools are appropriate, how they should be integrated into existing platforms and how their educational effectiveness should be evaluated.

Implications for Educational Media Professionals

AI should not necessarily be understood as a threat to educational media professionals. Instead, it can automate repetitive production activities and allow professionals to concentrate on higher-level creative decisions. The media professional of the AI era may therefore become less focused on manually performing every production task and more focused on creative direction, storytelling, quality control, accessibility and pedagogical communication.

Recommendations

Based on the discussion, the following recommendations are proposed.

First, Nigerian educational institutions should adopt an augmentation-oriented AI policy rather than treating AI primarily as an automation technology. Institutional policies should distinguish between appropriate AI assistance and inappropriate substitution of human intellectual work. Second, universities should establish continuous professional development programmes that equip lecturers, instructional designers, librarians and educational media professionals with AI literacy and human–AI co-creation skills. Third, AI literacy should include critical evaluation of AI outputs. Students and teachers should be taught that AI-generated information is not automatically accurate. Fourth, institutions should establish human validation protocols for AI-generated educational media. No AI-generated instructional material should be used in formal teaching without appropriate review. Fifth, Nigerian institutions should encourage the development of culturally relevant educational media. AI-generated materials should incorporate Nigerian contexts, examples, languages and experiences rather than simply reproducing generic global content.

Conclusion

The emergence of artificial intelligence has created a fundamental opportunity to rethink educational media production. AI can now generate text, images, audio, video and other forms of educational content at a speed and scale that were previously difficult to achieve. However, the availability of these capabilities does not automatically constitute educational innovation. The central challenge is to determine whether AI will be used to replace human educational work or to augment it. This paper has argued for the latter. Human–AI co-creation provides a framework through which artificial intelligence can expand the creative and productive capabilities of teachers, instructional designers, educational technologists and media professionals while preserving human pedagogical judgement and accountability. Within this model, humans define educational purposes, contextualise content, evaluate AI outputs and retain responsibility for the final product, while AI contributes speed, generative capacity, multimodal production and opportunities for experimentation. The movement from automation to augmentation is consequently more than a change in terminology. It represents a shift in the philosophy of educational technology. Automation asks, *"What can AI do for us?"* Augmentation asks a more important question: *"What can educators and learners accomplish when human intelligence and artificial intelligence work together responsibly?"*

For educational media production, the answer lies in co-creation. AI can generate possibilities, accelerate production and expand access to multimodal resources, but humans provide purpose, context, creativity, judgement and accountability. The most promising educational future is therefore neither purely human nor purely artificial. It is human-centred, AI-augmented and collaboratively designed.

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DEVELOPMENT AND VALIDATION OF AN EFFICIENT COMPUTER-BASED ASSESSMENT PLATFORM FOR NIGERIAN HIGHER INSTITUTIONS

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Abstract

Assessment provides the evidence upon which student achievement, progression and certification in higher education are determined. In Nigerian higher institutions, rising enrolment, continued dependence on paper-based examinations and administrative inefficiencies have placed considerable strain on examination administration, grading, record management and result processing. Although computer-based assessment has gained wide acceptance, many available systems serve narrow institutional contexts, privilege objective testing, or lack comprehensive validation, thereby limiting their suitability for large-scale implementation. This study proposes the development and validation of an efficient computer-based assessment platform designed specifically for Nigerian higher institutions. The platform integrates assessment creation, question-bank management, automated scoring of objective items, secure user authentication, result management and usability considerations within a single web-based environment. A research and development design is adopted, anchored on the Technology Acceptance Model but extended beyond perceived usefulness and perceived ease of use to include functionality, technical quality, usability, performance and user acceptability. Validation involves educational technology experts, computer science experts and students, using an experts' validation questionnaire, an ISO/IEC 25010-based software quality instrument and an adapted System Usability Scale. The platform is expected to improve assessment administration, reduce administrative workload, strengthen examination security and support timely result processing, contributing to educational technology by combining pedagogical validation with software quality evaluation.

Keywords: Computer-based assessment, educational technology, higher education, assessment platform, software validation, Nigeria

Introduction

Assessment occupies a central position in higher education because it supplies the evidence upon which learning, progression, certification and institutional quality assurance depend (Adom, Adu-Mensah, & Dake, 2020). Nigerian universities, polytechnics, monotechnics and colleges of education rely on effective assessment systems to determine students' academic achievement and professional competence. As enrolment expands, institutions experience growing pressure on examination administration, grading, record management and result processing, intensifying the search for technology-driven approaches capable of improving efficiency while preserving credibility and fairness (Ubi, Bassey, Anagbogu, & Joseph, 2021).Computer-based assessment has

emerged as one of the most significant innovations in educational evaluation (Malec, 2020). Unlike paper-based examinations, it supports electronic test administration, automated scoring of objective items, secure data storage, immediate feedback and efficient result management. Technological advances have extended it beyond multiple-choice testing to online assignments, electronic portfolios and learning analytics, so that assessment has become a continuous digital process supporting both instructional improvement and institutional decision-making (Pusa & Dinçer, 2025).

Implementation in Nigeria nevertheless remains constrained by infrastructural, technical and pedagogical challenges. Unstable electricity supply, weak connectivity, limited ICT facilities, inadequate technical support and uneven digital competence continue to affect adoption (Dan'inna, 2024). Existing platforms frequently serve specific examinations or institutions without addressing the broader requirements of Nigerian higher education, and many institutions therefore operate hybrid systems. Effectiveness depends not only on technical capability but also on educational suitability. An effective platform should support multiple assessment formats, secure delivery, role-based user management, automated scoring and reliable data storage, while remaining accessible to lecturers, students and administrators (Andreatos, Vomvyras, & Douligeris, 2022). Previous studies have examined students' perceptions of computer-based testing (Okocha, 2022; Rabiu, Kehinde, Amuda, & Kadiri, 2020), developed institution-specific systems (Abah, Honmane, Age, & Ogbule, 2022), or evaluated existing platforms (Gamage, Ayres, & Behrend, 2022). Few have combined software development with comprehensive validation involving educational technology experts, computer science experts and students within the Nigerian context.

Statement of the Problem

The increasing student population has substantially increased the administrative burden associated with conventional assessment. Examination printing, invigilation, manual marking, score computation, result compilation and record management demand considerable human and financial resources while increasing the likelihood of delay and error (Ubi et al., 2021). Although computer-based systems have addressed some of these challenges, many remain limited by difficulties relating to usability, infrastructure, security, restricted assessment formats and inadequate response recovery (Israel et al., 2024). Many were also developed for specific institutions or specialised purposes and may not reflect the regulatory requirements, infrastructural realities and pedagogical expectations of Nigerian higher education, and few have been validated by educational technology experts, computer science experts and students simultaneously. There consequently remains a need for an efficient platform supporting both educational effectiveness and technical reliability.

Aim and Objectives

The main objective of this study is to develop and validate an efficient computer-based assessment platform for Nigerian higher institutions. Specifically, the study seeks to:

1. develop an efficient computer-based assessment platform suitable for Nigerian higher institutions;
2. determine educational technology experts' assessment of the functionality and usability of the platform;
3. determine computer science experts' assessment of its technical quality and performance; and
4. determine students' assessment of its usability and acceptability.

LITERATURE REVIEW

Assessment in Higher Education

Assessment provides systematic evidence for evaluating students' learning, monitoring instructional effectiveness and supporting educational decision-making (Adom et al., 2020). It extends beyond the assignment of grades to the collection, interpretation and application of information supporting curriculum improvement, progression, certification and quality assurance, and therefore serves developmental, diagnostic, formative and summative purposes. Nigerian higher institutions commonly employ continuous assessment alongside end-of-semester examinations, permitting performance to be evaluated through assignments, projects, practical work and quizzes. Rising enrolment has nevertheless made conventional administration progressively more demanding for lecturers and administrative staff.

Computer-Based Assessment

Computer-based assessment refers to the electronic creation, administration, scoring, storage and management of assessments using computers or other digital devices (Malec, 2020). It supports automated scoring, electronic response recording, immediate feedback and secure storage of examination records, and has been extended to learning management system assessments, electronic portfolios and performance analytics. Adoption has accelerated because institutions require faster result processing, greater security and better management of large student populations, although effectiveness depends on appropriate design, adequate infrastructure and users' capacity to interact effectively with the technology.

Features of an Effective Assessment Platform

Educationally, a platform should enable lecturers to create varied assessment formats, organise question banks, assign marks, schedule examinations, accommodate objective and essay questions, provide timely feedback and maintain accurate records (Andreatos et al., 2022). Technically, it should provide secure authentication, role-based access control, encrypted communication, automated backup, reliable timing, question randomisation, secure result storage and compatibility with institutional infrastructure (Dhirani, Armstrong, & Newe, 2021; Karim, Kanaker, & Zarqou, 2021). Because Nigerian institutions often operate under infrastructural constraints, offline capability, automatic response recovery, low-bandwidth operation and local network deployment

assume particular importance, alongside usability, accessibility, interoperability and integration with institutional information systems (Pusa & Dinçer, 2025).

Existing Computer-Based Assessment Platforms

The Joint Admissions and Matriculation Board computer-based testing system represents Nigeria's largest implementation of computer-based assessment, having improved examination security, reduced impersonation and malpractice, standardised administration and accelerated result processing (Owo & Green, 2025). Implementation nevertheless depends heavily on stable infrastructure, adequate technical support and reliable examination centres, as difficulties during recent administrations demonstrate (Adeoye, Obi, Nafiu, & Soliu, 2025). Other widely used platforms include Google Forms, which offers a cost-effective environment for classroom assessment but limited examination security (Chekhratova, 2023); Canvas, which supports outcome-based assessment and institutional analytics (Burrack & Thompson, 2021); and Moodle Quiz, which offers extensive customisation, automated scoring and detailed feedback (Gamage et al., 2022). Their effectiveness in developing contexts remains constrained by infrastructure, connectivity and technical expertise.

Challenges in Nigerian Higher Institutions

Infrastructure remains the most significant barrier. Unstable electricity supply, inadequate computer laboratories, unreliable connectivity, limited technical personnel and high implementation costs frequently disrupt assessment activities, while server failure and equipment malfunction reduce user confidence (Dan'inna, 2024; Israel et al., 2024). Student experience also matters, as computer anxiety, uneven digital competence, unfamiliarity with interfaces and concerns about fairness during technical disruption affect both performance and acceptance (Rabiu et al., 2020). Validity and academic integrity present further challenges, since the expanding use of artificial intelligence, cybersecurity threats and data privacy concerns require robust authentication, secure data management and examination security measures (Dhirani et al., 2021).

Research Gap

Previous studies have advanced understanding of computer-based assessment by investigating students' perceptions, developing institution-specific systems and evaluating individual applications (Abah et al., 2022; Okocha, 2022). Many focused on a single institution, discipline or category of users, while others emphasised either technical performance or user perception without integrating educational suitability, software quality and user acceptability within one validation framework. This study addresses these limitations by developing a platform specifically for Nigerian higher institutions and validating it through three complementary perspectives.

Theoretical Framework

The study is anchored on the Technology Acceptance Model developed by Davis, which explains adoption through perceived usefulness and perceived ease of use (Zaineldeen, Li, Koffi, & Hassan, 2020). Perceived usefulness denotes the extent to which users believe a technology improves their performance, while perceived ease of use denotes the degree to which it is perceived as requiring

minimal effort; together these shape attitudes, behavioural intentions and eventual acceptance. The model offers an appropriate framework for understanding how lecturers and students perceive the developed platform, since a technically sound system may still record low adoption where users find it difficult to navigate or fail to recognise its educational value (Zakariya, Alotaibi, Alrashood, & Alrosaa, 2026). It has been criticised for giving limited attention to organisational and infrastructural factors (Malatji, Eck, & Zuva, 2020), a criticism particularly pertinent in Nigeria. This study therefore applies it alongside broader measures of software functionality, technical quality, system performance, usability and user acceptability.

METHODOLOGY

The study adopts a research and development design because it focuses on the design, development and validation of a computer-based assessment platform. The process involves identifying assessment requirements, designing the system architecture, implementing key functionalities and validating the completed system through expert evaluation and user assessment. The approach combines software development with systematic evaluation, ensuring that the platform satisfies both educational and technical requirements. Validation involves three categories of participants. Educational technology experts evaluate instructional appropriateness, functionality and usability; computer science experts assess technical quality and software performance; and students evaluate the platform after direct interaction with it. Purposive sampling is employed for the expert groups on the basis of qualification and professional experience, while students are drawn from institutions in which the platform is deployed for trial. Data are collected using three structured instruments: the Educational Technology Experts' Validation Questionnaire; the ISO/IEC 25010-Based Computer Science Experts' Validation Questionnaire; and an adapted System Usability Scale for students. Descriptive statistics, principally means, standard deviations and percentages, are employed to summarise the evaluation results and to determine the overall suitability of the developed platform for implementation within Nigerian higher institutions. The proposed platform is designed as an integrated web-based assessment environment supporting secure, efficient and user-friendly assessment administration. Rather than functioning solely as examination software, it supports assessment planning, delivery, scoring, record management and system administration.

This study is still on going

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FROM AUTOMATION TO AUGMENTATION: ARTIFICIAL INTELLIGENCE-DRIVEN DIGITAL LITERACY SKILLS FOR REIMAGINING TEACHING AND LEARNING ECOSYSTEMS IN BASIC EDUCATION

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Abstract

Artificial Intelligence (AI) is reshaping educational technology by shifting instructional practices from automation to augmentation, where intelligent technologies support rather than replace teachers and learners. This paradigm shift has created opportunities for adaptive learning, intelligent tutoring systems, learning analytics, educational chatbots, and multimedia-enhanced instruction that personalize learning experiences and improve educational outcomes. However, successful participation in AI-enabled learning environments requires learners to possess adequate digital literacy skills that extend beyond basic computer operation. This paper examines digital literacy as a critical educational competency for reimagining teaching and learning ecosystems in the AI era. Specifically, it discusses how information and data literacy, communication and collaboration, digital content creation, digital safety and security, problem-solving, and digital citizenship enable learners to effectively engage with AI-powered educational technologies. Anchored on Constructivist Learning Theory, Connectivism Theory, and the Technology Acceptance Model, the paper argues that AI should augment human intelligence rather than automate educational processes. It further highlights the implications of AI for educational technology, curriculum innovation, teacher professional development, adaptive learning, and learner engagement within Nigeria's basic education system. The paper concludes that strengthening digital literacy competencies among learners and teachers is fundamental to achieving equitable, inclusive, ethical, and sustainable AI integration in education. It recommends curriculum reforms, investment in digital infrastructure, AI literacy programmes, and continuous professional development to prepare learners for lifelong participation in intelligent learning ecosystems.

Introduction

The twenty-first century has witnessed unprecedented technological transformation driven by Artificial Intelligence (AI), big data, cloud computing, robotics, machine learning, and intelligent automation. These technological innovations are fundamentally changing how individuals communicate, work, solve problems, and acquire knowledge. Education, being one of the most dynamic sectors of society, has experienced significant changes as AI increasingly becomes integrated into teaching, learning, assessment, curriculum delivery, and educational management. Rather than merely digitizing traditional classroom practices, AI is redefining educational

processes by creating intelligent, personalized, and adaptive learning environments that support both teachers and learners.

Educational Technology has evolved considerably over the past few decades. Earlier applications of technology in education focused primarily on automation—using computers to perform repetitive instructional and administrative tasks such as grading, attendance management, scheduling, and content delivery. While automation improved efficiency, it offered limited opportunities for learner-centered instruction. The emergence of AI has introduced a new paradigm known as educational augmentation, in which intelligent technologies complement human capabilities by enhancing creativity, decision-making, collaboration, and personalized learning. Under this paradigm, teachers remain central to instruction while AI functions as a cognitive partner that enriches teaching and learning rather than replacing educators. The conference theme, *"From Automation to Augmentation: Reimagining Teaching and Learning Ecosystem in the AI Era,"* reflects this transition. Automation is no longer viewed as the ultimate objective of educational innovation. Instead, emphasis is placed on leveraging AI to improve learner engagement, foster creativity, promote inclusion, strengthen critical thinking, and facilitate lifelong learning. AI-powered technologies such as intelligent tutoring systems, adaptive learning platforms, learning analytics dashboards, educational chatbots, virtual laboratories, multimedia simulations, and automated formative assessment tools have become essential components of modern educational ecosystems.

Despite these remarkable innovations, the educational benefits of AI cannot be fully realized without adequate digital literacy. Digital literacy is increasingly recognized as a foundational competence for effective participation in technology-enhanced learning environments. It encompasses the knowledge, skills, attitudes, and ethical behaviours required to access, evaluate, create, communicate, and manage digital information responsibly. In AI-supported educational contexts, digital literacy extends beyond technical competence to include critical evaluation of AI-generated content, responsible interaction with intelligent systems, digital collaboration, data privacy awareness, cybersecurity, computational thinking, and ethical decision-making. The Organisation for Economic Co-operation and Development (OECD) and the European Commission recently emphasized that AI literacy for primary and secondary education should prepare learners to understand AI systems, critically evaluate AI outputs, recognize opportunities and risks, and use AI ethically and creatively. This demonstrates that digital literacy and AI literacy are complementary competencies that educational systems must develop simultaneously to prepare learners for future workplaces and digital citizenship.

Within Nigeria, increasing government investment in ICT infrastructure, smart classrooms, internet connectivity, and digital learning initiatives demonstrates growing recognition of technology's importance in education. Nevertheless, many schools continue to experience inadequate infrastructure, limited teacher preparedness, unequal learner access to digital resources, and insufficient digital literacy competencies. Consequently, many learners are unable to maximize the opportunities presented by AI-enabled educational technologies. Basic education, comprising

primary and junior secondary education, represents the most appropriate stage for developing foundational digital competencies. Learners who acquire digital literacy skills during these formative years are better positioned to participate successfully in higher education, employment, and lifelong learning. Educational Technology therefore has the responsibility of designing learning environments that cultivate these competencies through innovative pedagogical practices and AI-supported instructional strategies.

Artificial Intelligence and the Evolution of Educational Technology

Educational Technology has progressed through several developmental stages, beginning with audiovisual instruction, computer-assisted instruction, e-learning, mobile learning, blended learning, and now AI-enhanced learning. The current phase represents a shift from technology as a delivery mechanism to technology as an intelligent learning partner. Artificial Intelligence refers to computer systems capable of performing tasks that traditionally require human intelligence, including reasoning, learning, language understanding, problem-solving, pattern recognition, and decision-making. In education, AI applications include:

- Intelligent Tutoring Systems (ITS)
- Adaptive Learning Platforms
- Learning Analytics
- Educational Chatbots
- Automated Assessment
- Predictive Analytics
- Virtual Learning Assistants
- Speech Recognition
- Multimedia Simulations
- Personalized Learning Systems

These technologies analyse learner behaviour, identify learning gaps, recommend personalized instructional materials, provide immediate feedback, and support differentiated instruction. Consequently, teachers can devote greater attention to mentoring, facilitating collaborative learning, and addressing individual learner needs while AI automates repetitive tasks. UNESCO advocates a human-centred approach to AI in education that safeguards ethics, privacy, equity, and meaningful learning while enhancing—not replacing—the role of educators.

Digital Literacy in the AI Era

The emergence of AI has expanded the meaning of digital literacy beyond operational computer skills. Digital literacy now encompasses a broad range of competencies that enable learners to thrive in intelligent digital environments. The six essential digital literacy skills relevant to AI-enhanced education are:

Information and Data Literacy

This involves the ability to locate, retrieve, evaluate, organize, and use digital information effectively. Learners should be able to distinguish reliable information from misinformation, verify AI-generated content, and make informed academic decisions using digital resources.

Communication and Collaboration

AI-powered learning environments encourage learners to communicate through digital platforms, collaborate on projects, participate in virtual classrooms, and engage in global learning communities while practising appropriate digital etiquette.

Digital Content Creation

Learners are expected to produce presentations, documents, videos, multimedia projects, infographics, podcasts, and interactive educational resources using digital technologies and AI-assisted creative tools.

Digital Safety and Security

This competency involves protecting personal data, recognizing cyber threats, maintaining cybersecurity, safeguarding privacy, and promoting responsible use of digital technologies.

Problem-Solving

Digital problem-solving enables learners to select appropriate technological tools, troubleshoot technical challenges, adapt to emerging technologies, and apply computational thinking to solve academic problems.

Digital Citizenship and Ethical AI Use

Learners must demonstrate responsible online behaviour, respect intellectual property, avoid plagiarism, understand algorithmic bias, and use AI tools ethically and transparently. UNESCO's guidance stresses that ethical governance, privacy protection, and human agency should remain central to educational AI implementation.

Conceptual Framework

This paper is underpinned by the view that Artificial Intelligence serves as an enabler of educational transformation through the development of learners' digital literacy competencies. Rather than replacing teachers, AI augments teaching and learning by providing intelligent support systems that facilitate personalized instruction, adaptive learning, immediate feedback, and data-informed decision-making. The conceptual framework proposes that AI-powered educational technologies enhance learners' digital literacy skills, which in turn contribute to improved academic achievement. Specifically, six dimensions of digital literacy are identified as critical competencies:

- Information and Data Literacy
- Communication and Collaboration
- Digital Content Creation
- Digital Safety and Security
- Problem-Solving
- Digital Citizenship and Ethical AI Use

These competencies enable learners to navigate AI-enabled learning environments effectively, engage in meaningful learning experiences, and improve academic performance.

The framework further recognizes that the successful implementation of AI in education depends on enabling factors such as teacher competence, technological infrastructure, institutional support, curriculum integration, and educational policies.

From Automation to Augmentation: Reimagining Teaching and Learning in the AI Era

Artificial Intelligence represents a significant shift from educational automation to educational augmentation. While automation focuses primarily on increasing efficiency through technology, augmentation emphasizes enhancing human capabilities through intelligent systems.

Automation in education typically involves repetitive tasks such as:

- Automatic grading of objective tests.
- Attendance management.
- Timetable generation.
- Administrative record keeping.
- Basic learning management systems.

Although these applications reduce teachers' workload, they contribute little to improving learners' higher-order thinking skills. Educational augmentation, however, transforms teaching and learning by creating opportunities for deeper engagement and personalized instruction.

Personalized Learning

AI-powered adaptive learning systems analyse learners' strengths, weaknesses, pace of learning, and preferences to provide individualized learning experiences. Instead of delivering identical lessons to all learners, AI recommends appropriate instructional materials based on each learner's progress. This personalization improves motivation, engagement, and academic performance.

Intelligent Tutoring Systems

Intelligent Tutoring Systems provide learners with individualized academic support outside the classroom. Unlike traditional software, AI tutors:

- identify misconceptions,
- provide immediate explanations,
- recommend additional practice,
- monitor learner progress,
- generate personalized feedback.

These systems supplement teachers' instructional efforts and encourage independent learning.

Learning Analytics

Learning analytics involves collecting and analysing educational data to improve teaching and learning.

AI analyses data such as:

- assessment scores,
- attendance,

- participation,
- assignment completion,
- learning behaviours.

The results enable teachers to identify learners who require additional support before poor performance becomes evident. Consequently, interventions become proactive rather than reactive.

Adaptive Learning

Adaptive learning platforms continuously modify instructional content based on learner performance. Learners experiencing difficulties receive additional explanations and practice activities, while high-performing learners are provided with more challenging tasks. This flexibility supports differentiated instruction and promotes inclusive education.

Media and Multimedia in Education

Artificial Intelligence has transformed educational media through:

- intelligent educational videos,
- interactive simulations,
- augmented reality,
- virtual reality,
- speech recognition,
- automated captioning,
- multimedia content generation.

These technologies improve learner engagement and facilitate the understanding of abstract concepts.

Conclusion

Artificial Intelligence is transforming education by moving beyond automation towards educational augmentation. This transformation places greater emphasis on human-centered learning, personalized instruction, intelligent decision-making, and lifelong learning.Digital literacy has emerged as one of the most important competencies required for successful participation in AI-enabled educational ecosystems. Learners equipped with information literacy, communication skills, digital content creation abilities, cybersecurity awareness, problem-solving competencies, and ethical digital citizenship are more likely to benefit from adaptive learning technologies and intelligent educational systems.

Recommendations

Based on the discussions presented in this paper, the following recommendations are made:

1. AI literacy should be integrated into the basic education curriculum alongside digital literacy.
2. Governments should increase investment in educational technology infrastructure, including internet connectivity and smart classrooms.

3. Continuous professional development should be provided for teachers on AI-enhanced pedagogy and digital instructional design.
4. Schools should adopt adaptive learning platforms that personalize learning experiences.
5. Educational institutions should establish policies promoting ethical AI use, learner privacy, and cybersecurity.
6. Learners should be provided with opportunities to develop digital content creation and computational thinking skills.
7. Partnerships among government, universities, technology companies, and international organizations should be strengthened to promote responsible AI integration in education.

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TRANSFORMING EXPERIENTIAL LEARNING WITH IMMERSIVE EXTENDED REALITY: AUGMENTED REALITY, VIRTUAL REALITY, AND MIXED REALITY INTEGRATION IN TEACHING BASIC SCIENCE IN JUNIOR SECONDARY SCHOOLS IN LAGOS STATE.

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Abstract

Experiential learning theory holds that learners construct durable understanding by acting within, and reflecting on, concrete experience rather than by passively receiving information. In many Lagos State junior secondary schools, however, Basic Science is routinely taught through recitation and static diagrams because laboratories, equipment, and demonstration materials are limited by cost, safety, and time. Extended reality (XR), the umbrella term for augmented reality (AR), virtual reality (VR), and mixed reality (MR), offers a way to simulate concrete experience where the physical conditions for it are absent. This study reports the results of a descriptive survey of 120 Basic Science teachers drawn from public and private junior secondary schools in Lagos State, undertaken to establish the availability, extent of utilization, and perceived barriers to XR adoption, and to compare public and private school access. Only 37 teachers (30.8%) reported having any XR resource in their school, concentrated in roughly six schools overall; access was sharply skewed by school type, with 79.5% of private-school teachers reporting XR access against 7.4% of public-school teachers, a difference that a chi-square test of independence confirmed was highly significant, $\chi^2(1) = 60.80$, $p < .001$, with private-school teachers approximately 48 times more likely than their public-school counterparts to have XR access. Among the minority with access, utilization was modest: only 24.3% of teachers used XR frequently or very frequently, while 64.8% used it only rarely or occasionally, and most reached fewer than 100 students. Teachers ranked curriculum-content alignment, funding, teacher training, internet connectivity, and electricity as the most severe barriers to adoption. These findings confirm, with primary evidence, the resource and equity concerns anticipated in the conceptual literature and provide an empirical baseline for policy and future intervention. The study situates these results within Kolb's experiential learning cycle, reviews the Nigerian and international literature on XR in education, and closes with implementation considerations and recommendations for the Lagos State Ministry of Education, teacher training programmes, and future researchers.

Keywords: extended reality, augmented reality, virtual reality, mixed reality, experiential learning, instructional technology, Basic Science, Lagos State secondary education

Introduction

Secondary education in Nigeria is expected to prepare learners not merely to recall facts but to observe, experiment, and reason about the physical and social world. This expectation is most explicit in Basic Science, the junior secondary subject whose curriculum assumes that learners will handle apparatus, observe reactions, and manipulate models to make abstract concepts concrete. Kolb's theory of experiential learning formalizes this assumption, describing learning as a cycle that moves from concrete experience through reflective observation and abstract conceptualization to active experimentation (Kolb, 1984, as widely applied in subsequent educational technology research). Where concrete experience is unavailable, the cycle is broken at its starting point, and instruction tends to default to verbal description and rote memorization. In Lagos State, as in much of Nigeria, the conditions for concrete experience in science subjects are frequently constrained. Many public junior secondary schools operate without functional laboratories, and where laboratories exist, consumables and specimens are often inadequate for full class sizes. Field-based and demonstration-based alternatives are similarly limited by cost, class size, and logistics, a constraint documented directly in a recent nationwide study of geography field trips in Nigerian secondary schools (Ajani, 2025).

Extended reality (XR) technologies, an umbrella term covering augmented reality (AR), virtual reality (VR), and mixed reality (MR), have matured over the past decade to the point where they are increasingly proposed as a means of restoring concrete, experience-based learning where physical resources are scarce. AR overlays digital content onto the physical environment through a smartphone, tablet, or headset; VR immerses the learner in a fully simulated environment; and MR blends the two, allowing digital and physical objects to coexist and be manipulated together in real time. A recent bibliometric analysis found a substantial and accelerating volume of published research on XR in education between 2019 and 2024, evidence that the technology has moved from novelty to an established, if unevenly distributed, area of educational technology research (Jiang et al., 2024, as cited in the XR bibliometric literature). Nigerian researchers have begun to test AR and VR applications directly in local teacher education and secondary school contexts, with generally positive findings on learning outcomes, engagement, and retention (Adebesin et al., 2020; Adedokun-Shittu et al., 2020; Adedoja et al., 2020). Much of this research, however, has concentrated on teacher education institutions or single-subject interventions outside Lagos, leaving a gap in scholarship specific to the availability and classroom-level utilization of XR resources for Basic Science in Lagos State's junior secondary schools. This paper addresses that gap empirically: it reports primary survey data collected from 120 Basic Science teachers in Lagos State Education District II, situates the findings within experiential learning theory and the relevant literature, and closes with implementation considerations and recommendations.

Statement of the Problem

Basic Science in Lagos State junior secondary schools is, by curriculum design, meant to be taught experientially, through observation, demonstration, and hands-on activity. In practice, large class sizes, inadequate laboratory space, and limited consumable materials push many teachers toward chalkboard-based, descriptive instruction. This mismatch between curricular intent and classroom

practice is associated, in the broader Nigerian literature, with weak conceptual understanding and low retention in science subjects (Onojah et al., 2021; Otemuyiwa et al., 2020). Digital interventions such as computer-assisted instruction and mobile learning have been trialled in Nigerian secondary schools with encouraging results, but AR, VR, and MR specifically, which allow learners to interact with three-dimensional, dynamic representations of scientific phenomena rather than static images, remain comparatively unexplored at the classroom level, and the extent to which they are actually available to, and used by, Basic Science teachers in Lagos State had not been empirically established. Without a clear, evidence-based picture of what XR resources currently exist in schools, how they are used, and what barriers teachers face in adopting them, policy interventions and teacher training programmes risk being designed on assumptions rather than evidence. This study was motivated by that evidentiary gap.

Objectives of the Study

This study aims at

1. Clarifying the conceptual distinctions among augmented reality, virtual reality, and mixed reality as instructional technologies.

2. Situating the instructional value of XR technologies within experiential learning theory, and determine the AR, VR, and MR resources currently available to Basic Science teachers in Lagos State junior secondary schools.

Research Questions

The study was guided by the following research questions:

1. What AR, VR, and MR resources are currently available in Lagos State Education District II junior secondary schools?

2. To what extent do Basic Science teachers in the district utilize available XR resources in classroom instruction?

Conceptual Clarification

Augmented, Virtual, and Mixed Reality

Extended reality (XR) is the umbrella term for a spectrum of technologies that blend digital content with a learner's perception of reality to varying degrees. Augmented reality (AR) overlays computer-generated images, text, or three-dimensional models onto the user's view of the physical world, typically through a smartphone camera, tablet, or head-mounted display, while leaving the physical environment otherwise unchanged; a student pointing a tablet at a printed diagram of the human heart, for instance, might see a rotating three-dimensional model appear above the page. Virtual reality (VR) replaces the physical environment entirely with a computer-generated one, usually experienced through a headset, so that the learner's field of view is fully immersive; a VR field trip can place a student inside a volcano or a distant ecosystem that would be impossible to visit physically. Mixed reality (MR) occupies the middle ground, anchoring digital objects to the

physical environment so that the learner can manipulate virtual objects as though they were physically present and interact with real and virtual elements simultaneously. Recent conceptual work continues to treat these three modalities as points on a single reality-virtuality continuum, with XR functioning as the collective label under which AR, VR, and MR are discussed together in research and policy (Boel et al., 2024).

Experiential Learning

Experiential learning refers to the process by which learners build knowledge and skill through direct engagement with an activity, followed by reflection on that engagement. In science education, this typically means observing, manipulating, measuring, or experimenting rather than reading a description of a phenomenon. Because XR technologies can simulate manipulation and observation even when the physical apparatus or environment is unavailable, they are frequently positioned in the literature as tools for restoring the experiential dimension of learning under resource-constrained conditions, particularly in K-12 STEM subjects (Jiang et al., 2024, as cited in the XR bibliometric literature).

Theoretical Framework

This study is anchored in Kolb's experiential learning theory, which conceptualizes learning as a four-stage cycle: concrete experience, reflective observation, abstract conceptualization, and active experimentation. Learners are held to move most effectively through this cycle when they can act directly on the material to be learned rather than simply receive a verbal or textual description of it. Applied to XR in science education, an AR overlay that lets a student rotate a three-dimensional model of a cell provides concrete experience; the ability to pause, revisit, and manipulate that model supports reflective observation; accompanying teacher explanation supports abstract conceptualization; and structured tasks, such as labelling or answering questions about the model, support active experimentation. Because Kolb's cycle depends on the availability of concrete experience as its entry point, and because AR, VR, and MR are specifically designed to simulate concrete, manipulable experience, the theory provides a coherent rationale for treating XR integration as a means of completing, rather than replacing, the experiential learning cycle in classrooms where physical laboratories are limited. The low utilization rates reported later in this study suggest that, for most teachers surveyed, this cycle remains incomplete not for lack of theoretical rationale but for lack of access and support.

Literature Review

Global Trends in XR for Education

Research interest in XR for education has grown substantially over the past decade. A bibliometric analysis of publications indexed in Scopus between 2019 and 2024 identified over a thousand papers on extended reality in education and teaching, with publication volume rising sharply across the period, evidence of a field that has moved well beyond early-stage experimentation (Jiang et al., 2024, as cited in the XR bibliometric literature). A separate systematic review of seventy-two studies published between 2014 and 2024 found that XR applications cluster around professional

training, STEM education, soft-skills development, general education, and assessment, and that their effectiveness depends heavily on pedagogical design rather than on the technology alone; the same review flagged teacher readiness, equitable access, and global research disparities as persistent challenges to wider adoption. Despite this growth, reviews of the K-12 literature specifically note that research remains concentrated at the tertiary level, with secondary education comparatively under-studied and African contexts particularly under-represented in published work on mixed reality and academic engagement.

XR and Instructional Technology Research in Nigeria

A growing body of Nigerian research has tested AR and VR interventions, though most of this work has been situated in teacher education colleges or tertiary institutions rather than secondary schools. Adebesin et al. (2020) reported that AR technology enhanced pedagogy in Nigerian teacher education institutions, while Adedoja et al. (2020) found that a collaborative AR learning approach improved trainee teachers' academic performance. In a subject-specific application, Adedokun-Shittu et al. (2020) developed an AR instructional tool for geography learners in Osun State and found measurable gains in both academic performance and retention. Complementing these performance-focused studies, Adegbilero-Iwari et al. (2021) examined teachers' perspectives on VR integration and found broadly positive attitudes tempered by concerns about training and access, while Adeleke et al. (2021) identified specific factors, including cost, infrastructure, and digital literacy, that shape the adoption of AR technology in Nigerian institutions.

At the secondary school level specifically, a large-scale study by Ajani (2025) surveyed 420 senior secondary geography students across Nigeria's six geopolitical zones on their perceptions of XR-enabled virtual field trips, finding that field trips in Nigerian secondary schools are frequently constrained by insecurity, cultural barriers, and inadequate funding, and that students' digital literacy and gender shaped their perceptions of XR instructional tools as a viable substitute. This study is among the clearest pieces of Nigerian evidence that XR can plausibly substitute for physical field-based experiential learning at the secondary level, though it did not focus specifically on Lagos State or on Basic Science instruction. Related infrastructure research reinforces the access constraints documented in the present study's findings: Onojah et al. (2021) found that secondary school teachers' access to internet facilities for advanced instruction remains limited in many parts of Nigeria, and Oladosu et al. (2021) similarly documented uneven utilization of mobile ICT for learning among secondary school teachers in Ekiti State.

Instructional Technology in Lagos State Secondary Education

Research situated specifically within Lagos State's education districts provides useful methodological and contextual precedent for the present study, even where it does not address XR directly. Raheem-Folayinka et al. (2024) used a quasi-experimental, one-group pretest-posttest design across twelve schools sampled from Lagos State Education District V to evaluate the effect of flipped classroom strategies on economics learning outcomes, demonstrating that district-level, school-sampled designs are both feasible and already established practice in Lagos State education

research. In a similar vein, a flipped-learning study conducted with senior secondary Physics students across two schools in Lagos State Education District IV used a purpose-built, validated questionnaire alongside performance measures to compare technology-driven instruction with conventional teaching, and found that the technology-supported approach produced greater gains in student interest (Raheem-Folayinka et al., 2024). At the administrative level, Olujuwon et al. (2021) examined the characteristics that predict public primary school teachers' adoption of the Eko Excel pedagogical innovation in Lagos State, underscoring that technology adoption in the state's public school system is shaped as much by teacher characteristics and institutional support as by the availability of the technology itself. Together, these studies indicate that Lagos State's education districts provide a well-precedented setting for structured, questionnaire-based educational technology research, a precedent the present study followed.

Methodology

This study adopted a descriptive survey design, consistent with established precedent in Lagos State educational technology research, where structured questionnaires have been the dominant instrument (Raheem-Folayinka et al., 2024). The design was chosen because the study's purpose was to establish the current status of XR availability and utilization, and to compare that status across school types, rather than to test an intervention. The population comprised Basic Science teachers in public and private junior secondary schools within Lagos State. A total of 120 teachers responded to the questionnaire, comprising 81 public-school teachers and 39 private-school teachers, drawn using a multistage sampling technique: local government education areas within the district were listed and a subset randomly selected; schools within each selected area were then stratified by ownership type (public and private) and randomly sampled within strata; and Basic Science teachers within each sampled school were purposively included. This approach mirrors the multistage and stratified sampling strategies used in comparable Nigerian secondary school studies (Ajani, 2025; Raheem-Folayinka et al., 2024).

Data were collected using a structured questionnaire, the Availability and Utilization of Extended Reality Resources Questionnaire (AUERRQ), developed for this study. The instrument captured the presence and type of AR, VR, and MR tools in the school, ownership and duration of that access, facility placement, frequency of classroom use, number of students reached, and teachers' rating of fifteen potential barriers to adoption on a five-point scale. The instrument was subjected to face and content validation by experts in educational technology and measurement and piloted outside the main sample prior to full administration, following the validation approach used in comparable Lagos State instruments (Raheem-Folayinka et al., 2024).

Following ethical clearance and permission from the relevant education authorities, questionnaires were administered in person to sampled teachers. To answer the research question on differences between public and private schools, a chi-square test of independence was applied at the 0.05 level of significance, and an odds ratio was computed to express the magnitude of the disparity in access.

Results and Findings

Overall, only 37 of the 120 teachers surveyed (30.8%) reported having any AR, VR, or MR resource available in their school. This access was highly concentrated: available XR resources were traceable to approximately six schools in total, comprising one public pilot school and roughly five private schools, out of all schools sampled in the district. Table 1 summarizes overall and school-type-specific availability.

Table 1. *XR Availability by School Type (N = 120)*

School Type	Teachers Surveyed	Teachers Reporting XR Access	% with Access
Public	81	6	7.4%
Private	39	31	79.5%
Overall	120	37	30.8%

Among the 37 teachers with access, VR headsets were the most common device type (28 teachers, 75.7%), followed by AR-enabled applications (19 teachers, 51.4%), 360-degree cameras or viewers (7 teachers, 18.9%), and dedicated MR devices (7 teachers, 18.9%); these categories were not mutually exclusive, as some schools reported more than one device type. In terms of ownership, close to half of available XR resources were school-owned (48.6%), with the remainder distributed across donor or NGO provision (16.2%), teacher-owned devices (16.2%), government-issued equipment (10.8%), and other sources (8.1%). Where XR resources existed, they were most often housed in ICT rooms (29.7%) or science laboratories (27.0%), with just under a third of schools (32.4%) reporting XR resources placed in both types of facility. Reported duration of access skewed recent: 32.4% of teachers with access had held it for less than one year and 35.1% for one to two years, while only 13.5% reported more than five years of access, suggesting that XR adoption in the district, where it exists at all, is a comparatively recent development rather than an established practice.

Utilization among teachers with access to XR resources was modest. Reported frequency of classroom use was: never, 10.8%; rarely, 27.0%; occasionally, 37.8%; frequently, 18.9%; and very frequently, 5.4%. Combined, only 24.3% of teachers used XR frequently or very frequently, while 64.8% used it only rarely or occasionally, indicating that even where XR resources are physically present, they function chiefly as an occasional supplement rather than a routine instructional tool.

Table 2. *Reported Frequency of Classroom XR Utilization*

Frequency of Use	% of Teachers
Never	10.8%
Rarely	27.0%
Occasionally	37.8%
Frequently	18.9%
Very frequently	5.4%

The reach of XR-based instruction, measured by the approximate number of students exposed to it, was similarly limited: 5.4% of teachers reported reaching no students, 48.6% reported reaching between 1 and 50 students, 32.4% reported reaching 51 to 100 students, 10.8% reported reaching 101 to 200 students, and only 2.7% reported reaching more than 200 students. When asked to identify the main challenges limiting utilization, teachers most frequently cited unreliable electricity (62.2%), followed by curriculum alignment (51.4%), lack of technical support (48.6%), insufficient time (43.2%), inadequate devices (40.5%), lack of training (37.8%), and unreliable internet connectivity (37.8%).

Teachers rated fifteen potential barriers to XR adoption on a five-point scale, with higher mean scores indicating a more severe perceived barrier. Curriculum-content alignment (M = 4.38), funding (M = 4.36), and teacher training (M = 4.36) emerged as the three most severe barriers, closely followed by internet connectivity (M = 4.33), electricity (M = 4.32), cost (M = 4.27), and technical support (M = 4.23). Barriers related to classroom management and confidence, including classroom space (M = 3.65), lesson integration (M = 3.64), student distraction (M = 3.54), safety (M = 3.39), administrative resistance (M = 3.29), policy (M = 3.25), and low teacher confidence (M = 3.12), were rated as comparatively less severe, though still substantial on the five-point scale. This pattern indicates that structural and resource-based barriers, rather than teacher attitude or classroom-management concerns, are the dominant obstacles to XR adoption for Basic Science instruction in the district.

Discussion

These findings extend the Nigerian literature on XR in education from teacher-education and single-subject contexts (Adebesin et al., 2020; Adedoja et al., 2020; Adedokun-Shittu et al., 2020) into the specific case of Basic Science instruction in Lagos State junior secondary schools, and they do so with primary evidence rather than projection. Three findings warrant particular attention.

First, overall availability remains low: fewer than a third of teachers surveyed have any XR resource at all, and that access is concentrated in a small number of schools rather than distributed broadly across the district. This is consistent with international reviews describing K-12 XR adoption as uneven and African contexts as under-represented in both research and, evidently, in classroom practice (Jiang et al., 2024, as cited in the XR bibliometric literature). Second, even where XR resources are present, utilization is modest rather than routine. Nearly two-thirds of teachers with access use XR only rarely or occasionally, and reach is limited to fewer than 100 students for the large majority of teachers. Read against Kolb's experiential learning cycle, this suggests that XR's theoretical promise, restoring concrete experience where physical laboratories are absent, is only partially realized in practice, and that presence of technology is not sufficient for its instructional integration. Electricity, curriculum alignment, and technical support, the top-cited utilization challenges, point toward infrastructural and pedagogical-design barriers rather than teacher unwillingness, echoing the finding from international reviews that XR's instructional value depends on pedagogical design and support structures rather than on the technology in isolation.

Conclusion and Recommendations

This study set out to establish, with primary data, the availability, utilization, and perceived barriers to extended reality adoption for Basic Science instruction in Lagos State Education District II junior secondary schools, and to compare access across public and private schools. The findings show that XR access remains rare overall (30.8% of teachers), concentrated in a handful of mostly private schools, modestly utilized even where present, and dramatically more available to private-school teachers than to their public-school counterparts, a disparity confirmed by a highly significant chi-square association and an odds ratio of 48.44. Curriculum alignment, funding, and teacher training were identified as the most severe barriers to adoption. These results confirm, with empirical evidence, the resource and equity concerns anticipated in the conceptual and international literature, and they extend Nigerian XR research beyond its current concentration in teacher education and tertiary contexts into the specific case of junior secondary Basic Science instruction in Lagos State.

On this basis, it is recommended that:

1. The Lagos State Ministry of Education prioritize public junior secondary schools in any XR procurement or pilot programme, given the extreme disparity in current access documented in this study.

2. Teacher professional development programmes incorporate structured AR and VR training alongside existing ICT training, given that teacher training was rated among the most severe barriers to adoption.

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AWARENESS, ACCESSIBILITY, AND UTILIZATION OF ARTIFICIAL INTELLIGENCE TOOLS IN THE TEACHING AND LEARNING OF BIOLOGY IN SELECTED SENIOR SECONDARY SCHOOLS IN LAGOS STATE

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Abstract

Artificial Intelligence (AI) is increasingly reshaping science instruction globally, yet its integration into Biology teaching in Nigerian secondary schools remains uneven. This study examines the awareness, accessibility, and utilization of AI tools including generative AI platforms, virtual laboratories, and intelligent tutoring systems in the teaching and learning of Biology among Biology teachers and Senior Secondary School Two (SSS II) students in selected senior secondary schools in Lagos State. Guided by three specific objectives, the study examines the relationship between awareness of AI tools and their utilization in Biology instruction; determines the influence of accessibility of AI-powered hardware and software on utilization; and establishes whether significant differences exist in awareness, accessibility, and utilization between public and private schools. Anchored on the Technology Acceptance Model (TAM) and Connectivism Learning Theory, the study adopts a descriptive survey design with a correlational approach. A multi-stage sampling technique will be used to draw 300 respondents (20 Biology teachers and 280 SSS II students) from ten senior secondary schools (five public, five private) across Education Districts IV and VI of Lagos State. Data will be collected using a validated, researcher-developed instrument the Awareness, Accessibility, and Utilization of AI Tools in Biology Questionnaire (AAUAI-BQ) and analyzed using descriptive statistics (mean, standard deviation) and inferential statistics (Pearson Product Moment Correlation and Independent Samples t-test) at the 0.05 level of significance. This paper reports the conceptual and methodological foundation of an ongoing study, together with the anticipated pattern of results derived from the literature reviewed; data collection and analysis are in progress. The study is expected to reveal the extent of the implementation gap in AI-supported Biology instruction and to highlight infrastructural and training-related barriers, particularly across the public–private school divide, with implications for teacher professional development, ICT policy, and curriculum integration.

Keywords: *Artificial Intelligence, Biology education, awareness, accessibility, utilization, secondary schools, Lagos State*

Introduction

The global educational landscape is undergoing significant transformation driven by the Fourth Industrial Revolution, with Artificial Intelligence (AI) evolving from a specialized computer-science domain into a critical instructional tool (Okoli, 2023). In education, AI now supports personalized learning pathways, intelligent tutoring, and automated feedback (Shrivastava, 2024). This shift is especially relevant to Biology, a discipline built around abstract and dynamic processes DNA replication, cellular respiration, protein synthesis that traditional lecture-based

methods often struggle to convey. AI-driven tools such as 3D modeling and virtual simulations allow learners to interact with biological systems in immersive, risk-free environments, improving comprehension and retention (Jantakun et al., 2025). The successful integration of AI into Biology instruction, however, depends on three interlocking factors: awareness (knowledge that such tools exist and what they can do), accessibility (availability of the infrastructure devices, connectivity, power needed to use them), and utilization (the extent to which they are actually applied in practice). A shortfall in any one of these can blunt the educational impact of AI, regardless of how sophisticated the tools themselves become.

Within Nigeria, adoption remains uneven relative to peers such as South Africa and Kenya, despite policy attention from the Federal Ministry of Education (2024). Evidence suggests that while general AI awareness is growing, subject-specific application in science education lags behind (Nuru & Adamu, 2025). Lagos State Nigeria's technological and economic hub offers a particularly instructive setting: government programmes such as EKOEXCEL have expanded ICT access in some public schools, yet a marked disparity persists, with some students engaging advanced AI tools for scientific learning while others remain limited to basic text-generation applications (Alimi et al., 2026). Compounding this, weak teacher training, limited technical expertise, and poor alignment between AI tools and the Biology curriculum constrain effective use even where access exists (Odili & Ebiye, 2025). Despite growing interest in AI adoption in education broadly, there is limited empirical evidence on awareness, accessibility, and utilization specifically for Biology instruction among senior secondary students in Lagos State. This study addresses that gap.

Statement of the Problem

Biology education in Nigerian secondary schools continues to face overcrowded classrooms, inadequate laboratory equipment, and difficulty teaching abstract concepts such as molecular genetics and biochemical pathways through traditional methods. In principle, AI-powered virtual laboratories, intelligent tutoring systems, and adaptive learning platforms should help bridge this resource gap by enabling personalized instruction and immersive simulation (Okonkwo & Mante, 2024). In practice, an implementation gap appears to persist across Senior Secondary Schools in Lagos State. Preliminary observation suggests many Biology teachers and students hold only a superficial awareness of AI tools, often treating them as shortcuts for basic assignments rather than as scientific aids (Tejuosho, 2026). Where awareness exists, accessibility remains a major constraint: reliable internet connectivity, stable power supply, and adequate processing hardware are unevenly distributed between well-resourced private schools and public institutions (Nwaokugha & Abiakwu, 2024; Akinfalabi et al., 2025). As a result, actual utilization of AI for deep conceptual learning in Biology remains critically low, with teachers lacking pedagogical training to integrate these tools and students often navigating them without structured guidance (Nuru & Adamu, 2025). Left unaddressed, this risks widening the digital divide in Nigerian science education (Omotosho, 2026). This study investigates the extent of this problem in selected schools within Lagos State.

Objectives of the Study

The general objective is to examine the awareness, accessibility, and utilization of AI tools in the teaching and learning of Biology in selected senior secondary schools in Lagos State. Specifically, the study seeks to:

Examine the relationship between awareness of AI tools and their utilization in teaching and learning Biology in senior secondary schools in Lagos State.

Determine the influence of accessibility of AI-powered hardware and software on the utilization of AI tools in teaching and learning Biology.

Determine whether significant differences exist in awareness, accessibility, and utilization of AI tools between public and private senior secondary schools.

Research Questions

Is there a significant relationship between awareness of AI tools and their utilization in teaching and learning of Biology in selected senior secondary schools in Lagos State?

How does the accessibility of AI-powered hardware and software influence the utilization of AI tools in the teaching and learning of Biology in selected senior secondary schools in Lagos State?

Is there a significant difference in the awareness, accessibility, and utilization of AI tools between public and private senior secondary schools in Lagos State?

Research Hypotheses

H01: There is no significant relationship between the level of awareness of AI tools and their utilization in the teaching and learning of Biology in selected senior secondary schools in Lagos State.

H02: Accessibility of AI-powered hardware and software does not significantly influence the utilization of AI tools in the teaching and learning of Biology in selected senior secondary schools in Lagos State.

H03: There is no significant difference in the awareness, accessibility, and utilization of AI tools between public and private senior secondary schools in Lagos State.

Literature Review

Studies on AI in education document a growing but uneven trajectory. Chen, Chen, and Lin (2022), reviewing OECD secondary science teachers, found that awareness of AI applications outpaced structured pedagogical use, a pattern echoed in Nigerian contexts by Eze et al. (2022) and Okeke and Nwosu (2023), who identify infrastructure and training gaps as the principal constraints on digital-technology adoption in science teaching. Within Biology specifically, Cooper and Tang (2024) report that generative AI and adaptive virtual laboratories improved conceptual

understanding among high-school Biology students where access was reliable, underscoring that accessibility not merely awareness determines instructional payoff. Locally, Akanbi and Ofoegbu (2020) and Nwaokugha and Abiakwu (2024) document persistent digital-infrastructure disparities between urban public and private schools in Lagos State, a divide this study tests directly through its public–private comparison (H03). Taken together, the literature suggests awareness, accessibility, and utilization are conceptually distinct but empirically interdependent constructs — motivating the correlational design adopted here.

Theoretical Framework

The study is anchored on two complementary frameworks. The Technology Acceptance Model (Davis, 1989) explains utilization as a function of Perceived Usefulness and Perceived Ease of Use, both shaped by external variables such as infrastructure and digital literacy — mapping directly onto this study's accessibility construct (which conditions ease of use) and awareness construct (which shapes perceived usefulness). Connectivism (Siemens, 2005; Downes, 2007) complements TAM by framing AI systems as non-human 'nodes' within a learner's knowledge network, particularly suited to a discipline like Biology where dynamic, evolving scientific knowledge benefits from networked, AI-supported inquiry rather than purely teacher-centered delivery. Together, TAM explains the individual cognitive and infrastructural conditions for adoption, while Connectivism situates that adoption within the broader shift toward networked, technology-mediated science learning.

Methodology

The study adopts a Descriptive Survey Research Design with a correlational approach, appropriate for examining existing conditions, relationships, and group differences without manipulating variables. The research is delimited to Education District IV (Apapa, Surulere, Lagos Mainland) and Education District VI (Mushin, Oshodi-Isolo, Ikeja) of Lagos State, selected for their mix of public and private institutions and socioeconomic diversity. The population comprises Biology teachers and SSS II students in public and private senior secondary schools within the selected districts. A multi-stage sampling technique will be used: Stage 1 stratifies schools by type (public/private); Stage 2 purposively selects ten schools (five public, five private) via cluster sampling; Stage 3 randomly selects respondents within each school — two Biology teachers and 28 SSS II students per school yielding a total sample of 300 respondents (20 teachers, 280 students). Data will be collected using a self-developed, structured questionnaire the Awareness, Accessibility, and Utilization of AI Tools in Biology Questionnaire (AAUAI-BQ) comprising four sections: (A) demographic information; (B) ten items on awareness of AI tools; (C) ten items on accessibility of AI-powered hardware and software; and (D) ten items on utilization of AI in Biology teaching and learning. Sections B–D use a 4-point Likert scale (Strongly Agree = 4 to Strongly Disagree = 1), with a criterion mean of 2.50 distinguishing high/positive from low/negative responses. Face and content validity will be established through review by the researcher's supervisor and two experts in Science and Technology Education at the University of Lagos. Reliability will be assessed via a pilot study with 20 SSS II students and 5 Biology teachers

outside the main sample, using Cronbach's Alpha, with a coefficient of 0.70 or above regarded as acceptable. Data will be analyzed using SPSS version 29.0. Descriptive statistics (mean, standard deviation) will summarize response patterns against the 2.50 criterion mean. Inferential statistics Pearson Product Moment Correlation for H01 and H02, and Independent Samples t-test for H03 will test the stated hypotheses at the 0.05 significance level.

Conclusion

This paper has presented the conceptual and methodological foundation of an ongoing study investigating awareness, accessibility, and utilization of AI tools in Biology instruction in selected senior secondary schools in Lagos State, together with the anticipated pattern of results the study is designed to test. By anchoring the inquiry in TAM and Connectivism and applying a rigorous descriptive-correlational design across a stratified public–private sample,

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ARTIFICIAL INTELLIGENCE: THE GOOD, THE BAD, AND THE UGLY

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Abstract

Artificial intelligence (AI) has moved from a specialised research pursuit to a general-purpose technology reshaping education, health care, commerce, governance, and warfare. This paper offers a structured critical review of AI's trajectory using a tripartite "good, bad, and ugly" framework. The "good" examines documented benefits, including personalised and adaptive learning, diagnostic support in medicine, productivity gains, and expanded access to information and services, with particular attention to educational technology contexts in the Global South. The "bad" addresses well-established but remediable problems: algorithmic bias, labour displacement, academic integrity erosion, over-reliance and skill atrophy, and the environmental cost of large-scale computation. The "ugly" confronts harder, less reversible risks: mass-scale disinformation and synthetic media, pervasive surveillance, autonomous weaponisation, and the concentration of computational power in a small number of firms and states. Drawing on the literature in AI ethics, educational technology, and science and technology studies, the paper argues that these three categories are not independent; the same underlying capability (pattern recognition and generation at scale) produces benefit or harm depending on the governance, incentive, and pedagogical structures surrounding its deployment. The paper closes with recommendations for policymakers, institutional leaders, and educators seeking to maximise AI's benefits while containing its harms, emphasising human-centred design, AI literacy curricula, and regulatory frameworks appropriate to under-resourced educational systems.

Keywords: *artificial intelligence; AI ethics; educational technology; algorithmic bias; AI governance; generative AI; digital divide*

Introduction

Artificial intelligence has, within a single decade, moved from a peripheral academic subfield to a general-purpose infrastructure comparable in scope to electricity or the internet. Large language models, computer-vision systems, and recommendation engines now mediate how students learn, how clinicians diagnose disease, how firms hire and fire, and how citizens receive news. This ubiquity has produced a polarised public discourse: techno-optimists describe an era of abundance and augmented human capability, while critics warn of mass unemployment, algorithmic discrimination, and even existential risk to the species. This paper adopts the well-known heuristic of "the good, the bad, and the ugly" to organise a more disciplined appraisal. The distinction is not merely rhetorical. The "good" denotes benefits that are broadly uncontested and increasingly well evidenced. The "bad" denotes harms that are serious but largely addressable through better design,

regulation, and practice problems of degree rather than kind. The "ugly" denotes harms that are structurally difficult to reverse once entrenched: shifts in the information ecosystem, concentration of power, and risks that scale with the capability of the underlying systems themselves. Treating these as a single undifferentiated category of "AI risk" obscures the very different policy responses each requires. The paper is written from an educational standpoint and gives particular, though not exclusive, attention to implications for teaching, learning, and assessment, especially in resource-constrained systems such as those found in much of sub-Saharan Africa. However, because AI's effects are cross-sectoral, the review also draws on evidence from health care, labour economics, and information science to situate education within the wider technological landscape.

Conceptualising Artificial Intelligence

For the purposes of this review, artificial intelligence is understood broadly as computational systems that perform tasks perception, prediction, generation, and decision-making — that would ordinarily require human intelligence. This includes symbolic and rule-based systems, statistical machine learning, and the deep-learning and transformer-based architectures that underpin contemporary generative AI. The distinction matters because much of the public debate conflates narrow, task-specific AI (such as a grading assistant or a plagiarism detector) with the more speculative prospect of artificial general intelligence (AGI), a system with human-equivalent or superior general reasoning ability across domains. Almost all deployed educational and administrative AI in 2026 remains narrow AI; claims about AGI, while relevant to long-horizon policy, should not be allowed to dominate discussion of near-term classroom practice. A second useful distinction is between predictive AI (systems that classify, forecast, or rank, such as early-warning systems for student drop-out) and generative AI (systems that produce novel text, image, audio, or code, such as large language models). The two raise substantially different ethical questions predictive systems raise concerns chiefly about bias and fairness in decision-making, while generative systems raise additional concerns about authenticity, authorship, and the reliability of generated content and the paper treats them separately where the distinction is analytically important.

The Good: Documented Benefits of Artificial Intelligence

Personalised and Adaptive Learning

Adaptive learning platforms use predictive models of learner performance to sequence content, pace instruction, and target remediation at the level of the individual student rather than the class average. Meta-analyses in the educational technology literature have generally found small-to-moderate positive effects of intelligent tutoring systems on learning outcomes relative to conventional instruction, particularly in mathematics and procedural skill domains, with effects often comparable to one-to-one human tutoring in narrow task domains (VanLehn, 2011). For large, under-resourced classrooms typical of many public school systems, such systems offer a partial substitute for the individualised attention that teacher-to-student ratios make impossible to deliver at scale (Luckin et al., 2016).

Expanding Access and Reducing Administrative Burden

AI-enabled transcription, translation, and text-to-speech tools lower barriers for learners with disabilities and for speakers of minority languages, while automated scheduling, grading assistance, and broadsheet or result-processing systems reduce the administrative load on teachers and examination bodies. In contexts where manual collation of results across hundreds of schools is a persistent source of error and delay, well-designed automation can materially improve both accuracy and turnaround time (UNESCO, 2021).

Health, Science, and Productivity

Outside education, AI-assisted diagnostic imaging has demonstrated radiologist-level or superior sensitivity in detecting certain cancers and diabetic retinopathy in controlled studies, and protein-structure prediction systems have materially accelerated biomedical research. In the wider economy, AI-assisted coding, drafting, and data analysis tools have measurably increased output per worker in several controlled workplace studies, particularly benefiting less experienced workers by narrowing the performance gap with experts.

Democratising Expertise

Generative AI tools have lowered the cost of producing first drafts of documents, code, and instructional material, giving individuals and small institutions in low-resource settings access to a form of on-demand expert assistance that was previously the preserve of well-funded organisations. For a graduate student or a small school administration without a dedicated IT department, this is a genuine and substantial equalising force, even as it introduces new dependencies discussed in Section 4.

The Bad: Serious but Addressable Harms

Algorithmic Bias and Inequity

Machine learning systems trained on historical data reproduce and can amplify the biases present in that data. Well-documented cases include racially and gender-disparate error rates in commercial facial-analysis systems, biased automated hiring tools, and biased risk-scoring in criminal justice contexts (Buolamwini & Gebru, 2018). In education, predictive drop-out or admissions models trained on data from advantaged school systems risk systematically under-serving learners from under-represented backgrounds if deployed without careful recalibration and audit.

Labour Displacement and Skill Substitution

Economic analyses have consistently found that AI exposure is concentrated in cognitive, white-collar occupations previously considered insulated from automation clerical work, paralegal research, customer service, and increasingly entry-level analytical and creative tasks (International Labour Organization, 2023; Organisation for Economic Co-operation and Development, 2023). The distributional effects are uneven: workers able to use AI as a complement to their expertise tend to benefit, while those in roles that AI can substitute outright face displacement risk.

Academic Integrity, Over-Reliance, and Skill Atrophy

The widespread availability of generative AI has complicated assessment of authentic student work and raised concerns, still being empirically tested, about whether habitual reliance on AI-generated first drafts weakens the development of foundational writing, reasoning, and problem-solving skills a concern with clear precedent in earlier debates about calculators and, later, search engines, but arguably sharper given how convincingly generative language models can substitute for the entire cognitive task rather than a sub-step of it (Bender et al., 2021).

Environmental and Resource Costs

Training and operating large-scale AI models consumes substantial electricity and water for cooling, and the associated data-centre build-out has measurably increased the carbon intensity of some technology firms' operations even as those firms pursue renewable-energy commitments. This cost is frequently invisible to the end user of a Chabot or classroom tool, but is a legitimate part of any full accounting of AI's harms.

The Ugly: Structural and Harder-to-Reverse Risks

Synthetic Media and the Erosion of Shared Epistemics

Generative AI has sharply lowered the cost of producing convincing false text, images, audio, and video ("deepfakes"). Beyond individual instances of fraud or defamation, the more structural risk is epistemic: as synthetic content becomes indistinguishable from authentic content at scale, the evidentiary value of audio-visual media itself degrades, a phenomenon sometimes termed the "liar's dividend," in which genuine evidence can be dismissed as fabricated (Bender et al., 2021). This is a harder problem than any single instance of misinformation because it corrodes the infrastructure of trust that public discourse, journalism, and legal evidence depend upon.

Surveillance and the Erosion of Privacy

Computer vision and behavioural-prediction systems have enabled surveillance at a granularity and scale previously infeasible, from workplace monitoring to state-level facial-recognition networks. Once such infrastructure is built and normalised, it is politically and technically difficult to dismantle, and its existence changes the incentive structure for future governments regardless of the intentions of those who built it — a structural, not merely incidental, harm (Zuboff, 2019).

Autonomous Weapons and Security Risk

The application of AI to weapons targeting and lethal autonomous systems raises the prospect of reduced human oversight in life-and-death decisions and of an accelerating, destabilising arms-race dynamic among states, an area of active concern to international bodies (United Nations Institute for Disarmament Research, 2022). Unlike bias or job displacement, errors or escalation in this domain are not easily correctable after the fact.

5.4 Concentration of Power

The computational, data, and capital requirements of frontier AI development have concentrated the most capable systems in a small number of firms and states. This raises

governance questions distinct from any single harmful output: who sets the terms on which billions of people access cognitive infrastructure, and what recourse exists when those terms change unilaterally. Some AI ethicists and safety researchers additionally raise longer-horizon concerns about loss of meaningful human control over increasingly capable and autonomous systems (Bostrom, 2014; Russell, 2019); this remains a genuinely contested area among experts and is noted here as an open question rather than a settled finding.

Discussion: Why the Same Technology Produces Divergent Outcomes

A recurring theme across Sections 3 through 5 is that the underlying technical capability large-scale pattern recognition and generation is ethically neutral; it is the surrounding structure of incentives, governance, data provenance, and institutional capacity that determines whether a given deployment lands in the "good," "bad," or "ugly" category. An adaptive tutoring system trained on representative data, audited for bias, and used to support rather than replace teacher judgement, sits squarely in the "good" column; the same underlying architecture, deployed as an opaque admissions filter without recourse for affected applicants, moves toward the "bad." This suggests that policy attention should focus less on categorising "AI" as a monolithic good or bad and more on the specific conditions of deployment: data quality, transparency, human oversight, contestability, and distribution of benefit (Floridi, 2023).

For educational institutions specifically, this implies that the central task is not deciding whether to adopt AI but building the institutional capacity policy, training, and infrastructure to adopt it well. Institutions in lower-resource settings face a genuine dilemma here: the same tools that could most equalise access to expertise are also the ones such institutions are least equipped to audit, customise, or govern, since bias auditing, data-protection compliance, and vendor negotiation all require technical and legal capacity that is unevenly distributed.

Conclusion

Artificial intelligence is neither an unambiguous boon nor an unambiguous threat; it is a powerful, general-purpose capability whose consequences are shaped by the choices made in its design, deployment, and governance. The "good, bad, and ugly" framework used in this paper is useful precisely because it resists collapsing these consequences into a single verdict. The "good" personalised learning, diagnostic support, expanded access — is real and growing. The "bad" bias, displacement, integrity erosion is serious but substantially addressable through known governance practices.

Recommendations

For Policymakers and Ministries of Education

Develop AI-in-education policy frameworks that mandate bias auditing and data-protection impact assessments before large-scale procurement of predictive or generative AI systems.

Invest in national or regional AI literacy curricula so that students and teachers understand both the capabilities and the limitations of the tools they use.

Establish clear guidance distinguishing acceptable AI-assisted work from academic misconduct, rather than leaving the determination to individual instructors.

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Generative Artificial Intelligence as a Catalyst for Personalized Learning in Nigerian Higher Education: Opportunities, Challenges, and Future Directions

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Abstract

The emergence of Generative Artificial Intelligence (GenAI) has ushered in a transformative era in education, shifting instructional practices from automation to augmentation. As higher education institutions increasingly embrace digital technologies, Generative AI offers innovative opportunities to personalize learning, improve teaching effectiveness, and foster student engagement. This conceptual paper examines the role of Generative AI as a catalyst for personalized learning within Nigerian higher education. The paper explores the concepts of Generative AI and personalized learning, highlighting the capacity of AI-powered tools to generate adaptive instructional content, provide real-time feedback, support differentiated instruction, and facilitate learner autonomy. Despite these promising opportunities, several barriers hinder effective implementation in Nigeria, including inadequate digital infrastructure, limited AI literacy among educators, ethical concerns, data privacy issues, algorithmic bias, and the absence of institutional policies governing AI adoption. Drawing on Constructivist Learning Theory and Connectivism, the paper argues that Generative AI should complement rather than replace educators by enhancing instructional design and promoting meaningful learning experiences. The paper concludes that successful AI integration requires deliberate institutional planning, continuous professional development, ethical governance, curriculum redesign, and strategic investment in digital infrastructure. It recommends collaborative efforts among policymakers, educational institutions, technology developers, and educators to ensure that AI technologies are implemented responsibly and equitably for sustainable educational development in Nigeria.

Keywords: *Generative Artificial Intelligence, personalized learning, educational technology, higher education, Nigeria, AI-augmented education*

Introduction

Education has continually evolved in response to technological innovation, from chalkboards and overhead projectors to computers, the internet, and learning management systems. The rapid advancement of Artificial Intelligence (AI), particularly Generative Artificial Intelligence (GenAI), represents one of the most significant developments in educational technology in the twenty-first century. Unlike earlier digital technologies that primarily automated administrative or repetitive instructional tasks, Generative AI has introduced intelligent systems capable of producing human-like text, images, lesson plans, assessments, programming code, and other educational resources in response to user prompts. This shift signals a movement from educational

automation to educational augmentation, where technology works alongside educators to enhance teaching and learning rather than replacing human expertise.

The integration of Generative AI into education has attracted global attention because of its potential to transform teacher-centred instructional practices into learner-centred, adaptive, and personalized learning experiences. Tools such as ChatGPT, Google Gemini, Microsoft Copilot, Claude, Khanmigo, and Canva AI are increasingly adopted by educators and students to support lesson preparation, content creation, assessment design, feedback generation, language translation, research assistance, and collaborative learning. These technologies enable learners to receive individualized support that accommodates differences in learning pace, prior knowledge, interests, and academic abilities, thereby promoting more inclusive and engaging educational experiences.Personalized learning has emerged as a fundamental goal of contemporary education systems worldwide. Unlike the traditional one-size-fits-all model, it recognizes that learners possess diverse backgrounds, preferences, strengths, and challenges, and adapts instructional strategies accordingly. Generative AI strengthens this approach by offering adaptive content, intelligent tutoring, immediate feedback, and customized learning pathways that respond dynamically to learners' performance.

Within Nigerian higher education, the need for personalized learning has become increasingly urgent. Universities continue to face large class sizes, limited instructional resources, inadequate funding, lecturer shortages, and significant variations in students' academic preparedness. These challenges often hinder lecturers' ability to provide individualized support, and many students consequently struggle to receive timely feedback, personalized guidance, or differentiated instruction. Generative AI presents a promising opportunity to bridge these gaps by assisting educators in designing adaptive learning experiences while empowering students to become more independent, self-directed learners. This relevance aligns directly with the theme of the 8th International Conference and Workshop on Innovation, Technology and Education, *From Automation to Augmentation: Reimagining Teaching and Learning Ecosystems in the AI Era*, which emphasizes the transition from viewing technology merely as a tool for automating educational processes to recognizing its capacity to enhance human intelligence, creativity, instructional quality, and learner engagement.

Despite its advantages, integration into Nigerian higher education is accompanied by significant concerns, including inadequate technological infrastructure, inconsistent electricity supply, limited connectivity, digital inequality among students, insufficient AI competencies among educators, academic integrity issues, algorithmic bias, and questions of data privacy and security. Many institutions also lack policies to guide responsible adoption, and without strategic planning these challenges may undermine the transformative potential of AI. Against this background, this conceptual paper examines the role of Generative Artificial Intelligence as a catalyst for personalized learning within Nigerian higher education, exploring the opportunities presented, identifying the challenges affecting implementation, and proposing recommendations for responsible, equitable, and sustainable integration.

Statement of the Problem

Instructional practices in many Nigerian higher education institutions remain predominantly teacher-centred, characterized by large class sizes, limited opportunities for individualized learning, delayed feedback, and insufficient integration of emerging educational technologies, making it difficult for lecturers to address learners' varying abilities, interests, and preferences. Generative Artificial Intelligence presents unprecedented opportunities to address these challenges through adaptive learning, intelligent tutoring, automated feedback, and customized content. Implementation within Nigerian universities nevertheless remains limited, constrained by inadequate digital infrastructure, unreliable electricity, limited internet access, insufficient AI literacy among educators, ethical concerns, institutional resistance, and the absence of comprehensive AI policies. Moreover, while existing studies have extensively examined the technical capabilities of Artificial Intelligence, comparatively fewer have explored its potential as a strategic tool for personalized learning in the Nigerian context. This paper addresses that gap.

Purpose and Objectives of the Paper

The paper examines the potential of Generative Artificial Intelligence as a transformative tool for promoting personalized learning within Nigerian higher education institutions. Its specific objectives are to: examine the concept of Generative Artificial Intelligence and its relevance to higher education; explain the concept and significance of personalized learning in contemporary education; explore the opportunities offered by Generative AI for enhancing personalized learning in Nigerian higher education; identify the challenges associated with integrating Generative AI into teaching and learning; discuss the ethical considerations surrounding its educational use; and propose strategies for its effective and responsible integration into Nigerian higher education.

Research Questions

Six questions guide the paper, addressing the nature of Generative Artificial Intelligence and its transformation of higher education; the meaning and importance of personalized learning; the opportunities Generative AI provides for personalized learning in Nigerian universities; the challenges hindering its effective implementation; the ethical issues institutions should consider in adopting it; and the strategies that can enhance its responsible integration.

Literature Review

Concept of Artificial Intelligence

Artificial Intelligence refers to the simulation of human intelligence by computer systems that can perform tasks requiring reasoning, learning, problem-solving, decision-making, language understanding, and perception. Such systems analyse large volumes of data, identify patterns, make predictions, and continuously improve their performance through machine learning algorithms. Russell and Norvig (2021) describe Artificial Intelligence as the science and engineering of creating intelligent machines capable of performing functions that ordinarily require human intelligence, while UNESCO (2023) defines AI as computer systems that can interpret data, learn from experience, adapt to new information, and perform cognitive tasks with

varying degrees of autonomy. Over the last decade, AI has evolved from supporting administrative automation to facilitating intelligent educational experiences. Early applications focused on grading objective tests and managing student records, but advances in machine learning, natural language processing, and deep learning have enabled sophisticated interaction with users. The educational significance of AI lies not in replacing teachers but in augmenting their instructional capabilities, allowing educators to devote more attention to mentoring, facilitation, and critical thinking development.

Generative Artificial Intelligence

Generative Artificial Intelligence represents one of the most significant advancements within the broader field. Unlike conventional AI systems that primarily analyse or classify existing information, Generative AI creates entirely new content based on user instructions or prompts, including written documents, lesson notes, examination questions, images, computer programs, presentations, videos, and interactive learning materials. It relies on large language models, transformer architectures, and deep neural networks trained on extensive datasets to generate coherent and contextually relevant outputs; popular examples include ChatGPT, Google Gemini, Microsoft Copilot, Claude AI, Perplexity AI, Canva Magic Write, and Adobe Firefly. According to OpenAI (2024), Generative AI enables users to collaborate with intelligent systems in producing educational content, solving problems, brainstorming ideas, summarising information, and receiving personalised explanations tailored to individual learning needs. In education, its use extends beyond content creation to instructional planning, curriculum development, adaptive assessment, personalised tutoring, multilingual communication, accessibility services, and formative feedback. Consequently, it is increasingly viewed as an instructional partner rather than merely an educational technology tool, shifting educational technology from digital content delivery to intelligent knowledge generation.

Personalized Learning

Personalized learning tailors teaching methods, resources, assessments, and educational experiences to the unique characteristics of individual learners, recognising differences in prior knowledge, interests, abilities, motivations, and preferences. The United States Department of Education (2017) defines it as instruction that optimises learning by addressing each learner's strengths, needs, pace, and interests while providing flexibility regarding learning pathways. In such environments, students assume greater responsibility for their learning while teachers serve as facilitators who guide, monitor, and support them. Key characteristics of personalized learning include learner-centred instruction, flexible pacing, differentiated learning activities, continuous formative assessment, timely feedback, learner autonomy, competency-based progression, and technology-supported instruction. Researchers have consistently demonstrated that personalized learning improves learner motivation, increases engagement, enhances academic achievement, and supports lifelong learning competencies. However, implementing it within traditional higher education systems remains challenging because lecturers often manage large student populations,

making individualized instruction difficult without technological support. This challenge explains the growing interest in AI-powered educational systems.

Relationship between Generative AI and Personalized Learning

Generative AI serves as an enabling technology for personalized learning because of its capacity to adapt educational experiences to individual learners. Traditional learning management systems typically provide identical materials to all students; AI-powered systems, in contrast, analyse learner interactions and generate customized explanations, exercises, quizzes, summaries, and feedback based on individual needs. A student struggling with instructional design principles may request simpler explanations or additional exercises, while another may request advanced discussion or research materials. Lecturers can likewise create differentiated lesson plans for students of varying ability without manually preparing separate materials. This adaptability demonstrates why Generative AI is increasingly regarded as a catalyst for personalized learning rather than merely another educational technology tool.

Applications of Generative AI in Higher Education

Generative AI is rapidly transforming teaching and learning across universities worldwide, and its educational applications extend far beyond simple question answering. In intelligent tutoring, AI-powered tutors provide explanations, answer questions, identify misconceptions, and guide students through complex concepts in real time. In content development, lecturers generate lesson notes, lecture slides, laboratory manuals, instructional videos, assessment questions, discussion prompts, and case studies within significantly shorter periods. In assessment design, the technology assists educators in producing objective tests, essay questions, rubrics, marking guides, and competency-based assessments aligned with intended learning outcomes. Students receive immediate feedback on assignments, writing tasks, programming exercises, and problem-solving activities, enabling them to identify weaknesses before formal assessment. It also supports research by helping students brainstorm topics, summarise literature, organise ideas, and improve academic writing, while still requiring human critical evaluation, and advances accessibility through speech recognition, text-to-speech, captioning, translation, and personalised accommodations. Institutions further apply it to admission processing, student advising, scheduling, and learner support. Collectively, these applications illustrate the transition from automation to augmentation envisioned by the conference theme.

Empirical Review

Recent literature consistently reports improvements in student engagement, motivation, instructional efficiency, adaptive learning, feedback quality, accessibility, creativity, digital literacy, and collaborative learning, while equally identifying concerns about fabricated AI responses, overdependence, plagiarism, copyright, algorithmic bias, data privacy, unequal access, inadequate educator training, and weak institutional governance. Kasneci et al. (2023) found that Generative AI significantly improves personalised tutoring, academic writing support, and adaptive learning experiences when appropriately supervised by educators, concluding that it has

the potential to transform educational practices but requires ethical implementation and continuous human oversight. Crompton and Burke (2024), through a systematic review of AI applications in education, observed improvements in student engagement, instructional efficiency, and differentiated learning, but noted concerns relating to educator preparedness and institutional readiness. Zawacki-Richter, Marín, Bond, and Gouverneur (2021) similarly reported that research on AI in higher education has concentrated on technical development while paying limited attention to pedagogy and ethics. UNESCO (2023) emphasised that governments and institutions must establish policies addressing transparency, accountability, privacy, fairness, and equitable access. Within the Nigerian context, recent educational technology studies indicate growing awareness of AI among university lecturers and students, though adoption remains constrained by infrastructural limitations, inconsistent electricity supply, inadequate internet connectivity, limited digital competencies, and insufficient institutional investment. These findings underscore the importance of developing context-specific strategies that reflect Nigeria's educational realities while leveraging international best practices.

Theoretical Framework

This paper is anchored on two complementary learning theories: Constructivist Learning Theory and Connectivism Theory.

Constructivist Learning Theory

Constructivism, advanced by Piaget (1972) and further developed through the social constructivist work of Vygotsky (1978), proposes that learners actively construct knowledge through interaction with their environment rather than passively receiving information from teachers. According to constructivist principles, meaningful learning occurs when learners actively engage with learning tasks, connect new information with prior knowledge, solve authentic problems, collaborate with others, and reflect on learning experiences.

Generative AI supports constructivist learning by encouraging inquiry-based learning, exploration, experimentation, and personalised problem-solving. Rather than merely supplying answers, AI can guide learners through questioning, explanation, and reflection, thereby promoting deeper understanding. Students of Educational Technology, for instance, may use an AI assistant to generate instructional design scenarios, analyse educational problems, compare learning theories, or receive customised explanations suited to their existing knowledge levels. Generative AI thus serves as a cognitive scaffold that supports learners within their Zone of Proximal Development, consistent with Vygotsky's theory.

Connectivism Theory

Connectivism was proposed by Siemens (2005) to explain learning in the digital age, arguing that knowledge exists within networks comprising people, digital technologies, databases, and information systems. The theory holds that learning occurs through connections, that technology functions as an extension of human cognition, that the ability to locate information is often more

important than memorising it, that learning is continuous, and that decision-making itself constitutes a learning process. Generative AI aligns closely with Connectivism because AI systems become active participants within learners' knowledge networks. Students interact with intelligent systems to access information, solve problems, generate ideas, and collaborate during learning activities, and AI-powered systems facilitate continuous learning by connecting students with diverse information sources, personalised explanations, interactive discussions, and adaptive educational resources.

Relevance of the Theories

Constructivism explains how learners actively build understanding through meaningful interaction and personalised experiences, while Connectivism explains how digital technologies expand learning opportunities through intelligent networks and continuous access to knowledge. Together they support the argument that Generative AI should be viewed not as a replacement for educators but as an instructional partner that enhances personalised learning, promotes learner autonomy, and enriches educational experiences within Nigerian higher education.

Opportunities of Generative AI for Personalized Learning

Unlike conventional educational technologies that primarily facilitate content delivery, Generative AI actively participates in learning by generating content, providing explanations, adapting instruction to learners' needs, and supporting continuous interaction with knowledge resources. For Nigerian institutions, where rising enrolment places considerable pressure on instructional resources, this offers a practical means of enhancing learning quality without diminishing the central role of educators.

Intelligent Tutoring and Adaptive Learning Pathways

One of the most significant contributions of Generative AI is its ability to function as an intelligent tutor. Unlike traditional classrooms where lecturers must divide attention among large numbers of students, AI-powered tutoring systems can provide individualized assistance to every learner simultaneously. Students may ask questions repeatedly, request explanations in simpler language, or explore concepts in greater depth without fear of embarrassment, and the system adapts to the learner's level of understanding. A first-year undergraduate struggling with instructional systems design may request repeated explanations and analogies, while a stronger student requests advanced discussion of emerging design models; both receive personalized support despite studying the same course. Traditional higher education often requires all students to progress through identical materials at the same pace regardless of prior knowledge, disadvantaging both struggling and high-achieving learners. Generative AI addresses this through adaptive learning pathways: systems analyse learner interactions, monitor progress, and recommend activities appropriate to each student's competence, so that those demonstrating mastery advance while those experiencing difficulty receive remedial support. Adaptive learning thereby promotes mastery rather than time-based progression, which could significantly improve outcomes in the large undergraduate classes typical of Nigerian universities.

Personalized Feedback and Continuous Assessment

Timely, constructive feedback is among the most influential factors affecting student learning, yet providing detailed feedback to hundreds of students is extremely demanding in resource-constrained institutions. Generative AI enhances formative assessment by providing immediate, personalized, and detailed feedback on assignments, essays, programming exercises, lesson plans, and project reports. Rather than merely identifying incorrect responses, it explains why answers are inaccurate, suggests improvements, and guides learners toward deeper understanding. A postgraduate student preparing a research proposal may submit an introduction and receive comment on grammatical accuracy, academic writing quality, argument development, and referencing conventions, improving the work before formal submission while allowing lecturers to concentrate on higher-level evaluation and mentoring.

Content Development, Inclusion, and Lecturer Productivity

Preparing materials that accommodate learners of varying ability requires substantial time and expertise. Generative AI assists educators in producing differentiated resources such as lecture notes, lesson plans, presentations, practical activities, laboratory instructions, discussion questions, case studies, revision materials, quizzes, and competency-based assessments, each adaptable to different levels of complexity. A lecturer may request introductory materials for first-year students while simultaneously generating advanced analytical activities for postgraduate learners. Inclusive education requires that instruction accommodate learners regardless of disability, language background, or socio-economic circumstance. Generative AI provides accessibility features including text-to-speech, speech recognition, automatic captioning, translation, simplified reading materials, visual learning aids, and alternative assessment formats, so that students with visual or hearing impairments, learning disabilities, or limited English proficiency receive individualized support. Within Nigeria's multilingual environment, translation and language simplification tools can further improve comprehension. Lecturers themselves benefit substantially, since routine tasks such as preparing lesson notes, developing assessment questions, designing rubrics, summarising literature, drafting course outlines, and providing preliminary feedback can now be completed more efficiently. Reducing administrative workload enables greater attention to mentoring, facilitating discussion, supervising research, and designing innovative learning experiences, enhancing productivity without diminishing professional judgement.

Self-Directed Learning and Twenty-First Century Skills

Generative AI supports self-directed learning by serving as an always-available companion through which students independently explore unfamiliar concepts, seek clarification, revise difficult topics, and practise problem-solving outside scheduled hours. This is particularly valuable for working students, distance learners, and postgraduate researchers balancing academic responsibilities with professional and family commitments. Personalized experiences also increase engagement, since content reflects individual needs. Generative AI enhances engagement through

interactive conversation, immediate responses, scenario-based learning, simulations, and gamified activities; students of curriculum development might, for example, engage an AI system in designing materials for learners with special educational needs, promoting curiosity, creativity, and critical thinking. In the process, learners acquire competencies valued in contemporary workplaces: formulating effective prompts, evaluating AI-generated information critically, verifying evidence, solving authentic problems, communicating clearly, and making informed decisions. Responsible integration therefore teaches ethical, creative, and intelligent use of technology rather than passive dependence.

Support for Research and Implications for Nigerian Higher Education

Generative AI supports the research process by helping researchers identify gaps, refine topics, generate conceptual frameworks, explain methodologies, summarize literature, improve academic writing, and prepare presentations. Researchers must nevertheless critically evaluate AI outputs to ensure accuracy, originality, and academic integrity, since AI should complement rather than replace independent intellectual inquiry. Properly implemented, these capabilities can help Nigerian universities address longstanding challenges such as overcrowded classrooms, limited instructional resources, delayed feedback, and unequal access to quality educational support. Realizing the benefits, however, depends on institutional readiness, investment in digital infrastructure, lecturer capacity development, ethical governance, and policies promoting responsible use. Universities must therefore treat Generative AI as a strategic educational innovation aligned with national goals for producing digitally competent graduates, rather than as a substitute for educators.

Challenges and Ethical Considerations

Educational technologies do not operate independently of social, economic, cultural, and institutional realities. Successful integration requires more than introducing tools; it requires supportive infrastructure, human capacity development, ethical guidelines, institutional commitment, and policies ensuring responsible use.

Digital Infrastructure and Accessibility

Inadequate digital infrastructure is among the most significant barriers to AI integration, since Generative AI depends on reliable connectivity, electricity, appropriate devices, and technical support. Many universities continue to experience unstable electricity, limited broadband, high internet costs, inadequate computer facilities, and unequal access to devices among students, creating a digital divide in which only well-resourced students and institutions fully benefit. Without deliberate effort to address accessibility, AI may widen existing inequalities; government agencies, administrators, and technology stakeholders must therefore prioritize infrastructure investment as the foundation for sustainable adoption.

Limited AI Literacy Among Educators

Successful implementation depends significantly on educators' ability to understand, evaluate, and use AI technologies, yet many lecturers have limited knowledge of AI concepts, applications, and

ethical practices. Although some have begun exploring tools such as ChatGPT, many lack training in prompt engineering, AI-supported instructional design, evaluating AI-generated content, and managing AI-assisted classrooms, and may therefore either reject AI out of uncertainty or use it in ways that do not maximize its potential. Universities should establish structured AI literacy programmes addressing not only technical skills but also pedagogy, ethics, assessment redesign, and responsible digital citizenship.

Recommendations

Based on the discussion of opportunities, challenges, and future directions, the following recommendations are proposed.

1. Nigerian universities should develop comprehensive Artificial Intelligence policies addressing acceptable and unacceptable uses of AI tools, AI-assisted academic writing and research, transparency in disclosing AI usage, academic integrity procedures, data privacy, intellectual property, and accountability for AI-generated content.
2. Government agencies, university administrators, and private sector partners should prioritize investment in stable electricity supply, affordable and reliable internet connectivity, modern computer laboratories, cloud-based educational platforms, digital learning management systems, and technical support services.
3. Universities should establish regular professional development covering the capabilities and limitations of Generative AI, design of AI-enhanced learning experiences, effective prompting, evaluation of AI output, AI-supported assessment, and ethical concerns, positioning lecturers as leaders of AI transformation rather than passive users.
4. AI literacy should be integrated into university curricula as a general graduate competency across all fields rather than restricted to computer science, covering AI concepts, responsible use, recognition of bias and misinformation, digital privacy, ethical decision-making, and collaboration with intelligent technologies.

Conclusion

Generative Artificial Intelligence represents one of the most significant technological developments influencing the future of education. Its ability to generate content, provide personalized feedback, support intelligent tutoring, and adapt learning experiences presents enormous opportunities for higher education, and within Nigerian universities, where educators face large student populations, limited resources, and diverse learner needs, it offers a pathway toward more personalized, inclusive, and learner-centred experiences. Technology alone, however, cannot transform education. Success depends on human decisions, institutional readiness, ethical considerations, and strategic implementation, and challenges relating to infrastructure, educator preparedness, academic integrity, data privacy, algorithmic bias, and policy gaps must be carefully addressed.

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GENERATIONAL DEFINITIONS AS CORRELATE OF ARTIFICIAL INTELLIGENCE LITERACY SKILLS AMONG TECHNOLOGY EDUCATION LECTURERS IN UNIVERSITIES IN NIGERIA

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Abstract

Artificial intelligence (AI) literacy has become an essential skill for university teachers in this 21st-century AI era. This study investigated how generational affiliation correlates with the AI literacy of Technology Education Teachers (TETs) in universities in Nigeria. A quantitative correlational design was adopted, and data were collected from 143 TETs in south-west Nigeria and analyzed using descriptive statistics, independent samples *t*-test, one-way ANOVA, multiple regression, and Pearson correlation. Findings revealed that TETs generally demonstrated a high level of AI literacy (M = 4.48, SD = 0.57). However, significant generational differences were observed across AI perception, AI knowledge and skills, AI application and innovation, and AI ethics ($p < .001$), with Generation Z recording the highest AI literacy (M = 4.84, SD = 0.21), followed by Generation Y (M = 4.75, SD = 0.24), while Generation X recorded the lowest (M = 3.64, SD = 0.33). Multiple regression indicated that teaching experience ($\beta = -.486$, $p < .001$), generational affiliation ($\beta = -.465$, $p < .001$), and gender ($\beta = -.180$, $p < .001$) significantly predicted AI literacy, explaining 81.1% of the variance ($R^2 = .811$), while educational qualification was not a significant predictor ($p = .060$). AI literacy was strongly associated with generational affiliation ($r = -.776$, $p < .01$). The study recommends differentiated AI professional development programmes that address teachers' varying technological backgrounds and career stages.

Keywords: AI; AI Literacy; Technology Education Teachers; Generational Definition; AI perceptions

Introduction

Technology education contributes to the scientific and technological literacy of students by preparing them to understand systems, technical operations, and the history and development of technology (Blandow & Dyrenfurth, 1994; Yekinni & Ogbuanya, 2022). Technology Education Teachers (TETs) facilitate teaching and learning in classrooms and laboratories, guiding students toward useful membership of society (Ogbuanya & Yekinni, 2020a, 2020b). McKinsey estimates that 15% of global working hours will be automated and 47% of jobs, including teaching, are at high risk of automation by 2030 (Manyika et al., 2017; Ng et al., 2021), making digital literacy and increasingly AI literacy essential for every citizen, including TETs (Bawden, 2008). AI is steadily permeating education, from traditional methods to virtual classrooms and AI-supported instruction (Ning et al., 2025), with growing evidence of AI adoption at the university level for

teaching, learning, assessment, and administrative support (Crompton & Burke, 2023; UNESCO, 2026). AI Literacy (AIL) refers to the knowledge, understanding, skills, and value orientation that enable individuals to evaluate, interact with, and use AI technologies effectively and ethically (Ng et al., 2021; Long & Magerko, 2020; Miao et al., 2021). UNESCO (2021) emphasized AIL's significance for education during its "AI in Education" thematic conference. Teachers' AIL constitutes their capacity to thrive in the AI era (Ning et al., 2025) and is multidimensional, commonly comprising AI perception, AI knowledge and skills, AI application and innovation, and AI ethics (Ning et al., 2025; Long & Magerko, 2020; Zhao et al., 2022; Biagini et al., 2023). This study adopts Ning et al.'s (2025) four-dimension scale, developed specifically for professional teachers.

AI perception concerns educators' perceived usefulness and perceived ease of use of AI tools, anchored on the Technology Acceptance Model (Ning et al., 2025). AI knowledge and skills encompass the theoretical understanding and practical competencies TETs need to recognize and apply AI in educational settings (Long & Magerko, 2020; Pingmuang et al., 2025). AI applications and innovation capture TETs' capacity to integrate AI into instructional design and foster innovative teaching practice (Chiu & Chai, 2020; Younis, 2025). AI ethics refers to the fair, transparent, and legal principles teachers must observe when using AI-enabled resources, safeguarding privacy, fairness, and accountability (Celik, 2023a; Marshall et al., 2022; Nguyen et al., 2023). While AI adoption in Southwest Nigerian universities is growing, its extent and effectiveness remain unclear, partly because AI literacy among teachers is still limited (Akinyele, 2025; Lähdesmäki & Maunula, 2022). Many teachers lack adequate training in AI applications, benefits, and limitations, undermining confidence in using these tools (Abdullahi et al., 2025). A key contributing factor is disparity in familiarity and comfort with AI across age groups (Abdullahi et al., 2025), since generational cohort shapes technology use and professional growth (Akello, 2024; Crooks et al., 2020).

Scholars categorize individuals by birth year into cohorts such as Generation X (1965–1980), Generation Y/Millennials (1981–1996), and Generation Z (1997–2012) (Ezurike, 2024; Cottrell, 2026). Today's university workforce spans these generations (Dimock, 2019; Suša, 2025), and this study focuses on TETs across Generations X, Y, and Z. Digital literacy is generally reported as higher among younger generations (Akello, 2024; Chandna, 2024), though findings are inconsistent: some studies find Gen Z lacking key digital-literacy sub-skills despite being digital natives (McKee-Ryan, 2021; Bergson-Shilcock, 2020), while Generation X, despite not growing up with the internet, has adapted substantially to digital technologies (Akello, 2024; Perrin, 2019). Notably, Joskowicz and Slomovitz (2025) found age was not correlated with AI knowledge among engineers underscoring the need for further empirical clarity, particularly in Nigerian universities. Digital-inequality research also links gender, age, experience, education, and income to the digital divide (Lissitsa & Chachashvili-Bolotin, 2022; Van Dijk, 2020), yet studies examining demographic influences on TETs' AIL remain limited in Nigeria. Understanding these differences is fundamental for administrators and policymakers seeking to close the AI digital divide and plan effective training (Ezurike, 2025; Hargittai & Dobransky, 2017). This study therefore investigated generational definitions as correlates of AI literacy among TETs in Nigerian universities, guided by four research questions: (1) What is the level of AI literacy among TETs by generational cohort? (2) What is the impact of TETs' demographic profile on AI literacy? (3) Do demographic profiles predict AI literacy? (4) What is the relationship between generational definition and AI literacy?

Methodology

This study adopted a correlational survey design across seven public universities (2 federal, 5 state) offering Technology Education in south-west Nigeria. All 162 TETs in these institutions were surveyed. The instrument comprised a demographic section (age range, gender, qualification, teaching experience) and Section B, the Teachers' Artificial Intelligence Literacy Scale adapted from Ning et al. (2025) 35 items on a five-point Likert scale across four dimensions: AI perception (10 items, $\alpha = .909$), AI knowledge and skills (10 items, $\alpha = .943$), AI application and innovation (8 items, $\alpha = .931$), and AI ethics (7 items, $\alpha = .851$); combined scale $\alpha = .889$. Ethical approval was obtained from the University of Lagos ethics committee. Questionnaires were administered physically (two Lagos universities) and via Google Forms (five other universities). A total of 143 valid responses were returned (88% return rate). Data were analyzed using means, standard deviations, *t*-tests, ANOVA, Pearson correlation, and multiple regression. Interpretation followed: 3.50–5.00 = High, 2.50–3.49 = Moderate, 1.00–2.49 = Low AI Literacy (Deressa et al., 2022). Hypotheses were tested at $p \leq .05$.

Results

Table 1: Demographic Profile of the Research Participants

Variable	Category	n	%
Gender	Male	99	69.2
	Female	44	30.8
Qualification	Bachelor's Degree	22	15.4
	Master's Degree	42	29.4
	Doctoral Degree	79	55.2
Birth Year Range	1997–2012 (Gen Z)	44	30.8
	1982–1996 (Gen Y)	61	42.7
	1960–1981 (Gen X)	38	26.6
Teaching Experience	1–10 years	68	47.6
	11–20 years	34	23.8
	21–30 years	24	16.8
	31 years and above	17	11.9

Participants were predominantly male (69.2%), doctoral degree holders (55.2%), Generation Y (42.7%), and relatively early-career (47.6% with 1–10 years' experience).

Research Question 1: What is the level of AI literacy among TETs by generational cohort?

Table 2: AI Literacy Mean Ratings by Generational Cohort

Dimension	Gen Z (M±SD)	Gen Y (M±SD)	Gen X (M±SD)	Total (M±SD)
AI Perception	4.81 ± 0.25	4.76 ± 0.26	3.66 ± 0.38	4.48 ± 0.58
AI Knowledge & Skills	4.82 ± 0.27	4.65 ± 0.34	3.48 ± 0.38	4.39 ± 0.64
AI Application & Innovation	4.88 ± 0.21	4.78 ± 0.27	3.50 ± 0.39	4.47 ± 0.66
AI Ethics	4.85 ± 0.22	4.79 ± 0.26	3.92 ± 0.36	4.58 ± 0.48
Overall AI Literacy	**4.84 ± 0.21**	**4.75 ± 0.24**	**3.64 ± 0.33**	**4.48 ± 0.57**

The overall mean AI literacy score (4.48, SD = 0.57) indicated a high level. Generation Z recorded the highest overall AI literacy, followed closely by Generation Y, with both cohorts scoring high across all four dimensions. Generation X, though overall "high" per the adopted criterion (M = 3.64), recorded only moderate AI Knowledge and Skills (M = 3.48), indicating comparatively weaker technical competence relative to perception and ethics.

Research Question 2: What is the impact of demographic profile on TETs' AI literacy?

Table 3: t-test/ANOVA of Demographic Profiles on AI Literacy Dimensions

Variable	AI Perception	AI Knowledge & Skills	AI Application & Innovation	AI Ethics
Gen Z / Y / X (F)	197.582**	208.653**	291.978**	147.275**
Male / Female (t)	20.966**	25.833**	12.960**	17.796**
Bachelor's / Master's / Doctoral (F)	14.824**	10.412**	8.274**	13.654**
1–10 / 11–20 / 21–30 / 31+ yrs (F)	73.974**	101.499**	106.394**	68.393**

All demographic variables were significantly associated with AI literacy differences ($p < .001$). Generation Z scored highest across all dimensions, followed by Generation Y, with Generation X lowest. Male TETs recorded higher AI literacy than female TETs. Bachelor's and Doctoral holders generally outscored Master's holders. TETs with fewer years of teaching experience scored higher than more experienced TETs, with those having 31+ years recording the lowest, including moderate literacy in three of the four dimensions.

Research Question 3: Do demographic profiles predict TETs' AI literacy?

Table 4: Multiple Regression of Demographic Profiles on AI Literacy

Predictor	β	t	Sig.
Gender	−.180	−3.958	.000
Qualification	.082	1.896	.060

Predictor	β	t	Sig.
Generational difference	−.465	−9.717	.000
Teaching experience	−.486	−9.721	.000

Model: F(4, 138) = 147.771, $p < .001$, $R^2 = .811$

Demographic profiles significantly predicted AI literacy, explaining 81.1% of variance. Teaching experience was the strongest predictor (β = −.486), followed by generational difference (β = −.465) and gender (β = −.180). Educational qualification was not significant ($p = .060$).

Research Question 4: What is the relationship between AI literacy and generational definition?

Table 5: Correlation Matrix of AI Literacy and Generational Definition

Variable	1	2	3	4	5	6
1. AI Perception	1	.929**	.935**	.901**	.974**	−.738**
2. AI Knowledge & Skills		1	.924**	.919**	.976**	−.767**
3. AI Application & Innovation			1	.872**	.968**	−.776**
4. AI Ethics				1	.949**	−.709**
5. AI Literacy (overall)					1	−.776**
6. Generation Definition						1

Note. **Correlation is significant at the 0.01 level (2-tailed).

Generational definition was significantly negatively correlated with overall AI literacy ($r = −.776$, $p < .01$) and with all four dimensions, indicating that older generational cohorts recorded lower AI literacy while younger cohorts recorded higher AI literacy. The strongest relationship was with AI Application and Innovation; the weakest (though still strong) was with AI Ethics.

Discussion of Findings

This study found that TETs in Nigerian universities generally demonstrate high AI literacy, with Generation Z and Y consistently outperforming Generation X, particularly in AI knowledge and skills. This aligns with Suša (2025) and Nigerian studies (Ezurike, 2025; Omotayo, 2020) reporting that younger employees are typically more tech-savvy and adapt faster to new technology. Demographic characteristics gender, qualification, generational cohort, and experience significantly shaped AI literacy variation, consistent with digital-inequality research linking such factors to technology competence (Lissitsa & Chachashvili-Bolotin, 2022; Krueger et al., 2018). Teaching experience, generational cohort, and gender jointly predicted AI literacy, echoing calls for differentiated professional development that accounts for teachers' varied technological backgrounds and career stages (Naci & Tatli, 2024). The strong negative correlation between generational definition and AI literacy corroborates prior findings that digital-literacy disparities across age groups are shaped by differential access to and comfort with digital technologies (Akello, 2024; Kumar et al., 2022).

Conclusion

TETs in Nigerian universities generally demonstrate high AI literacy, indicating readiness to adopt AI-supported teaching. However, competence varies by generation: Generation Z scored highest

across all dimensions, followed by Generation Y, while Generation X showed comparatively lower AI knowledge and practical application. Teaching experience and gender also significantly predicted AI literacy, while educational qualification did not — suggesting that exposure to contemporary technology and career stage matter more than academic credentials. Effective AI integration in Technology Education requires institutional strategies addressing generational differences and promoting ongoing professional learning, ethical awareness, and collaborative knowledge sharing.

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A HUMAN-CENTERED FRAMEWORK FOR ARTIFICIAL INTELLIGENCE (AI) READINESS IN NIGERIAN UNIVERSITIES

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Abstract

This paper examines the institutional requirements for developing AI-ready universities in Nigeria by proposing a comprehensive framework that prioritizes human capacity augmentation rather than administrative automation. The study adopts a descriptive analytical approach organized around three interconnected pillars of institutional AI readiness: infrastructure, policy and governance, and ecosystem development. The analysis indicates that institutional AI readiness extends beyond broadband expansion to include faculty AI literacy, resilient energy infrastructure, standardized institutional data architecture, and sustainable partnerships with government agencies, among others. The paper concludes that the proposed Human Capacity Augmentation Framework sees AI as a pedagogical partner that enhances lecturers' instructional effectiveness, supports personalized learning, strengthens institutional decision-making, and improves educational quality without replacing academic professionals. The paper recommends that universities adopt holistic AI-readiness strategies integrating technological infrastructure with ethical governance, human capacity development, institutional data management, and collaborative innovation ecosystems.

Keywords: *Artificial intelligence, augmentation, automation, ecosystem development, governance and policy, infrastructure, human development, Nigerian universities.*

Introduction

Digital transformation initiatives in Nigerian higher education have historically emphasized internet connectivity, computer laboratories, and computer-based testing. While these investments improved access to digital technologies, they remain insufficient for preparing universities to deploy AI responsibly. There is a need for universities and sponsoring agencies such as the Tertiary Education Trust Fund (TETFund) to make a paradigm shift, repositioning future interventions toward AI-enabled institutional transformation rather than conventional ICT expansion (Adebayo & Salako, 2021). International policy discussions increasingly advocate a human-centred approach to AI adoption in education, emphasizing that AI should enhance rather than replace educators' professional judgement, creativity, and pedagogical expertise (UNESCO, 2023). UNESCO (2021) stresses the need for institutions to prioritize human agency, ethical governance, equity, and capacity building when integrating AI into educational systems. This human capacity augmentation perspective positions AI as an intelligent partner supporting lecturers in instructional design, formative assessment, student support, and learning analytics rather than as a substitute for academic professionals. This conceptual study, following Jaakkola's (2020) approach to theory synthesis, draws on two theoretical perspectives — Sociotechnical Systems Theory (Trist & Bamforth, 1951) and the Technology–Organization–Environment (TOE) Framework (Tornatzky & Fleischer, 1990) — to analyze the institutional conditions required for responsible AI adoption in Nigerian universities.

From ICT Readiness to AI Readiness

Digital transformation in Nigerian universities has progressed from basic computerization to institutional digitalization and, more recently, toward AI-enabled transformation. Early ICT adoption focused on access to computers, connectivity, and digital libraries, driven by the assumption that technological availability alone would improve educational quality (Yusuf, 2005; Holmes, 2019). However, evidence from developing contexts shows that technology adoption alone does not guarantee transformation, since institutional capacity, human competence, governance, and context strongly shape outcomes (Kirkwood & Price, 2014; Selwyn, 2022). AI represents a fundamental departure from earlier ICT interventions: AI systems analyze data, generate content, make predictions, and support decision-making rather than simply providing access to information (Ahmad et al., 2021). Institutional readiness for AI therefore requires a broader conception of digital maturity spanning infrastructure, organizational capability, ethical governance, and human expertise (Bond et al., 2024). AI readiness refers to an institution's capacity to strategically adopt, govern, and utilize AI in ways that enhance educational quality, effectiveness, research productivity, and societal contribution (Benaim & Lalloo, 2021).

Traditional Nigerian universities often deliver standardized instruction regardless of differences in prior knowledge, pace, or need (Imogie, 2002). AI offers opportunities to overcome these limitations by analyzing learner behaviour, generating personalized learning pathways, identifying engagement patterns, predicting academic difficulties, and recommending resources (Chen et al., 2020) improving academic support without proportionally increasing lecturer workload in large public universities (Lucky & Ochoyi, 2021). However, the educational value of AI depends on how institutions conceptualize its role. Selwyn (2022) contrasts a narrow *automation* approach — treating AI as a replacement mechanism prioritizing automated grading and administrative substitution with an *augmentation* approach that recognizes AI as a cognitive partner enhancing human expertise while keeping lecturers as central decision-makers, consistent with Sociotechnical Systems Theory.

Theoretical Foundations

Sociotechnical Systems Theory (STS). Originally developed by Trist and Bamforth (1951), STS holds that effective organizational performance emerges from optimizing both social and technical subsystems together, not from technological advancement alone. Applied to higher education, STS suggests that successful AI adoption requires more than installing AI platforms or expanding connectivity: universities must simultaneously develop human capabilities, policies, ethical frameworks, and organizational structures enabling meaningful interaction between people and intelligent systems. A university may possess advanced AI tools yet fail to achieve transformation if lecturers lack AI competencies, institutional data remain fragmented, or governance does not address ethical concerns. AI readiness should therefore be conceptualized as an institutional capability spanning infrastructure, professional capacity, ethical governance, and collaborative networks (Castillo-Martínez et al., 2024).

Technology–Organization–Environment (TOE) Framework. Developed by Tornatzky and Fleischer (1990), TOE proposes that technology adoption is shaped by three interconnected dimensions. The *technological* dimension concerns the availability, compatibility, and complexity of AI infrastructure — computing resources, data architecture, cybersecurity, learning management systems, and dependable energy, all of which demand more than conventional

bandwidth and connectivity. The *organizational* dimension concerns leadership, workforce capability, financial commitment, and policy structures; without organizational readiness, AI investments risk remaining underutilized. The *environmental* dimension concerns external factors government regulation, funding agencies, industry partnerships, and technology ecosystems, including bodies such as TETFund, the National Information Technology Development Agency (NITDA), and local innovation hubs.

Proposed Framework: The AI-Ready University Augmentation Model

This paper proposes the AI-Ready University Augmentation Framework (AI-RUAF), which argues that successful AI adoption requires universities to move beyond viewing technology as an isolated entity and instead develop an integrated ecosystem where technology, people, governance, and external partnerships interact. The framework shifts attention from technology-centred adoption toward human-centred institutional transformation — particularly relevant for Nigerian universities facing large enrolments, limited resources, and uneven digital capacity. It also responds to global calls for AI in education to be guided by transparency, inclusion, human agency, and ethical responsibility (UNESCO, 2023).

The framework proposes that AI readiness emerges from the alignment of three institutional pillars

Infrastructure Readiness, **Policy and Governance Readiness**, and **Ecosystem Readiness** which collectively support the ultimate goal of **Human Capacity Augmentation**: AI as a partner to lecturers, researchers, and administrators.

Figure 1: The AI-Ready University Augmentation Model

Layer	Core Focus	Key Components
Human Capacity Augmentation	AI as partner to lecturers, researchers, administrators	Pedagogical partnership, decision support
Infrastructure Readiness	Technical foundation	Reliable energy, data architecture, intelligent LMS, computing capacity
Policy and Governance Readiness	Ethical and regulatory foundation	AI governance, data protection, ethical standards, faculty AI literacy
Ecosystem Readiness	External collaboration	Government support, industry partnerships, EdTech collaboration, community innovation

a) Infrastructure Readiness. AI depends fundamentally on data quality, yet many universities operate fragmented systems for student records, examinations, and admissions (Bukar & Ndahi, 2015), limiting the ability to predict academic difficulties, identify dropout risk, and support evidence-based planning. An AI-ready institution needs unified data architecture: integrated Student Information Systems, secure databases, standardization protocols, APIs, and cybersecurity mechanisms aimed at creating meaningful, ethical institutional intelligence, not merely more data. Electricity reliability is a fundamental barrier: AI requires continuous computing operations, and unstable national supply creates server interruptions, hardware damage, and inconsistent platform availability (Omoniyi & Fadare, 2019). AI-ready universities must therefore integrate alternative energy solutions such as solar microgrids, hybrid inverters, and energy-efficient computing infrastructure.

Universities also need to migrate from conventional Learning Management Systems (LMS), which largely function as digital storage, toward intelligent LMS capable of monitoring resource access, assessment patterns, discussion participation, and engagement trends (Gbadamosi, 2018) — enabling lecturers to move from reactive teaching to proactive academic support, particularly valuable for managing large classes (Lucky & Ochoyi, 2021).

b) Policy and Governance Readiness. Because AI systems influence educational decisions and process personal information, universities must establish governance structures ensuring responsible adoption, including institutional AI strategies, ethical guidelines, data governance policies, algorithmic accountability, and professional development requirements. Multidisciplinary AI Governance Committees — drawing on education, computer science, legal, library science, student affairs, and quality assurance — should evaluate AI applications before deployment. Data protection is a critical concern, especially following Nigeria's Data Protection Act (NDPA) 2023. Universities generate significant volumes of sensitive data (demographic, academic, financial, LMS interaction), and AI adoption raises additional concerns since algorithms may process this data and generate decisions affecting students' educational experiences. International research emphasizes that AI governance requires transparency, accountability, fairness, and human oversight (Floridi et al., 2018; UNESCO, 2023). Universities must establish clear policies on acceptable AI use, data ownership, algorithmic transparency, cybersecurity, consent, and intellectual property; without effective governance, AI adoption may create new inequalities and vulnerabilities (Adebayo & Salako, 2021). Human capacity remains the most important determinant of successful AI adoption. Inadequate teacher preparation is historically one of the greatest barriers to effective technology integration (Ertmer & Ottenbreit-Leftwich, 2010). AI introduces competency requirements beyond traditional digital literacy — knowledge of AI capabilities and limitations, prompt engineering, AI-supported instructional design, ethical use, evaluation of AI-generated information, and redesigned assessment practices. Faculty AI literacy is particularly important because lecturers mediate between technology and students; rather than banning AI over plagiarism concerns, universities should build responsible AI-literacy programmes and evolve assessment toward process, creativity, reflection, and oral demonstration.

c) Ecosystem Readiness. Universities cannot build sustainable AI capability independently; they require partnerships with government funding agencies, technology companies, indigenous EdTech developers, research institutions, professional bodies, and surrounding communities (Sanusi et al., 2022). Nigerian universities must reposition from passive consumers of imported technology to active participants in AI innovation networks, functioning as knowledge hubs where research, teaching, community engagement, and entrepreneurship interact producing solutions reflecting local realities rather than imported assumptions.

TETFund remains one of the most significant drivers of infrastructure and academic development in Nigerian public tertiary institutions (Okojie, 2011), historically focused on physical infrastructure and staff development; AI capability should now be treated as a strategic investment rather than an additional cost. NITDA similarly plays an important role in digital innovation and cybersecurity awareness. Partnerships with indigenous EdTech developers can reduce dependence on imported solutions poorly matched to Nigerian infrastructure, language, and assessment realities, supporting technology sovereignty and strengthening the local EdTech sector. Finally, AI-ready universities should extend their technological resources beyond campus boundaries

through community AI-literacy programmes for secondary school teachers, administrators, small businesses, and community organizations.

Conclusion

The rapid emergence of AI represents a defining moment for Nigerian universities. The challenge is not merely whether AI will enter academic environments, but whether institutions possess the capabilities to adopt and govern it responsibly. Existing approaches to digital transformation — emphasizing connectivity, computer facilities, and bandwidth — are inadequate for the demands of the AI era. Institutional AI readiness requires a shift from a technology-acquisition mindset toward comprehensive transformation anchored in three interconnected pillars: infrastructure readiness, policy and governance readiness, and ecosystem readiness. Universities that successfully develop AI-ready ecosystems, integrating technology with human expertise, ethical responsibility, and institutional innovation, will be better positioned to improve educational quality, expand research capacity, support student success, and contribute to national digital transformation.

Recommendations

1. Universities should develop institutional AI transformation strategies aligned with goals in teaching, research, administration, and community engagement.
2. Digital infrastructure investment should move beyond bandwidth expansion toward comprehensive AI-ready infrastructure, including resilient energy and unified data architecture.
3. Institutions should establish AI governance structures to review applications before deployment, monitor ethical compliance, evaluate algorithmic bias, and protect institutional data.
4. Universities should implement compulsory AI literacy programmes for academic and administrative personnel, and pursue partnerships with government agencies and indigenous EdTech developers.

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Learning Experience Design in an AI-Integrated Gamified Learning Environment

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Abstract

This study investigated Learning Experience Design (LxD) in an AI-integrated gamified learning environment among secondary school biology teachers in Kwara state, Nigeria. Specifically, the study assessed teachers of awareness of LxD in AI-integrated gamified environments, examined the use of AI-integrated gamified strategies, identified key LxD components applied in classroom practice, determined teachers' perceptions of the effectiveness of AI-integrated gamified learning environment, investigated LxD implementation and challenges and also examined differences in adoption of LxD based on years of teaching experience. The study adopted a descriptive survey design, involving 234 secondary school Biology teachers determined using Cohen et al.'s (2018) sample size formula. Data were collected from secondary school biology teachers using a researcher-designed questionnaire. Descriptive statistics of mean and standard deviation were employed for research questions while inferential statistics (ANOVA) was used to test hypothesis at 0.05 level of significance. Findings revealed that teachers demonstrated high level of awareness and moderate utilization of AI-integrated gamified strategies, while interactive learning activities, personalized instruction, and immediate feedback emerged as the major LxD components commonly applied in instruction. Findings revealed that teachers perceived AI-integrated gamified learning environments as effective in enhancing students' motivation, engagement and learning outcomes. However, inadequate technological devices and infrastructure, insufficient time and training were identified as major implementation challenges. Findings revealed a significant difference in teachers' adoption of LxD based on years of teaching experience. The study concluded that effective integration of LxD within AI-driven gamified learning environments can significantly improve biology teaching and learning outcomes in secondary schools.

Keywords: Artificial Intelligence, Biology, Gamified Learning Environment, Learning Experience Design (LxD), Secondary School Teachers

Introduction

The rapid advancement of digital technologies has transformed educational practices worldwide, leading to innovative approaches that enhance teaching effectiveness and learner engagement. Among these innovations, Artificial Intelligence (AI) has emerged as a transformative technology capable of personalizing learning experiences, automating instructional processes, and providing adaptive support to learners (Abdulmumin et al., 2025). AI-driven educational systems analyze

learner data, deliver real-time feedback, and customize instructional content according to individual learning needs, thereby improving learning outcomes and fostering meaningful educational experiences (Bali et al., 2024). Consequently, AI is increasingly being recognized as a critical component of educational transformation in the twenty-first century.

In Nigeria, the adoption of AI in education is gradually gaining momentum as educators and policymakers explore its potential to improve teaching and learning processes. Jimba et al., (2024) observed that AI technologies can enhance personalized learning, facilitate adaptive instruction, and support data-driven educational decision-making. Similarly, Abubakar et al. (2024) reported that although students and educators demonstrate moderate awareness of AI tools, infrastructural limitations, inadequate technical support, and insufficient teacher training continue to hinder effective implementation. Furthermore, Ezurike and Akinsulire (2024) found that AI-powered tools such as ChatGPT can support independent learning, improve conceptual understanding, and increase learner engagement. These findings suggest that the successful integration of AI in education depends largely on educators' readiness and their ability to design effective and learner-centered instructional experiences.

Alongside the emergence of AI, gamification has gained considerable attention as an innovative pedagogical strategy for enhancing learner motivation and engagement. Gamification refers to the application of game elements such as points, badges, levels, rewards and challenges in non-game contexts to encourage participation and improve learning outcomes (Cheung & Ng, 2021). Recent studies have demonstrated the effectiveness of gamification in promoting active learning and improving academic achievement across various educational settings. Aliyu et al. (2025) reported that gamified instructional strategies significantly improved students' motivation and conceptual mastery in science-related subjects. Similarly, Olamoyegun and Ola-Adeniji (2025) found that gamification enhances active participation, collaboration and immediate feedback, thereby facilitating deeper understanding of scientific concepts.

In biology education, gamification has shown particular promise in addressing challenges associated with abstract and complex concepts. Owolarafe et al (2024) and Abdulahi et al. (2025) revealed that gamified learning applications significantly improved students' academic performance and attitudes toward biology. The interactive nature of gamified environments enables learners to visualize biological processes, engage in problem-solving activities, and participate actively in learning tasks (Adipat et al., 2021. Despite these benefits, the implementation of gamification in Nigerian schools remains constrained by inadequate technological infrastructure, limited access to digital devices, and insufficient teacher preparation (Olamoyegun & Ola-Adeniji, 2025). These challenges underscore the need for systematic approaches that can guide the effective integration of gamification into instructional practices.

The convergence of AI and gamification has led to the development of AI-integrated gamified learning environments, which combine the motivational benefits of gamification with the adaptive capabilities of artificial intelligence. Such environments provide personalized, interactive, and

data-driven learning experiences that respond dynamically to learners' needs and preferences Bolaji et al., (2025). According to Bali et al. (2024), AI-integrated systems support personalized instruction by analyzing learner performance and adapting educational content accordingly. Likewise, Abubakar et al. (2024) and Ezurike and Akinsulire (2024) emphasized that AI-enabled educational tools can improve learner engagement, provide immediate feedback, and facilitate individualized learning pathways. As a result, AI-integrated gamified environments have the potential to address limitations associated with traditional teaching approaches by fostering active participation, sustained motivation, and improved learning outcomes.

However, the effectiveness of AI-integrated gamified learning environments depends not only on the technologies employed but also on the quality of the learning experiences designed within those environments (Tawfik et al., 2024). This highlights the importance of Learning Experience Design (LxD), a learner-centered approach that integrates pedagogical principles, technology, and user-experience design to create meaningful and engaging learning experiences (Uysal, 2026). Unlike traditional instructional design, which primarily focuses on content delivery, LxD emphasizes learners' experiences, interactions, motivations, and emotional engagement throughout the learning process (Schmidt & Huang, 2022). By prioritizing usability, engagement, and learner satisfaction, LxD provides a framework for designing educational environments that are both effective and enjoyable.

Learning Experience Design has become increasingly relevant in technology-enhanced learning environments, particularly those involving AI and gamification). Effective learning experiences require the integration of pedagogical strategies with user-centered design principles to promote engagement and meaningful learning (Uysal, 2026). Supporting this view, Sakpere (2025) emphasized that incorporating interactivity, feedback mechanisms, and personalization into gamified learning applications significantly enhances learner engagement and knowledge retention. Similarly, Ezeanya et al. (2024) found that AI-driven educational tools improve social interaction, collaboration, and learner participation in digital learning environments. These findings align closely with the core principles of LxD, which focus on creating engaging, interactive, and learner-focused educational experiences.

Despite growing interest in AI, gamification, and Learning Experience Design, empirical research examining their integration within secondary school education remains limited. Existing studies have largely investigated AI and gamification as separate educational innovations, with little attention given to how teachers design and implement learning experiences within AI-integrated gamified environments. This gap is particularly evident in biology education, where students often encounter difficulties in understanding abstract concepts through conventional teaching methods (Abdulahi et al., 2025 : Reiss & Mujtaba, 2018). Furthermore, limited research has explored teachers' awareness, extent of use, perceptions, and challenges regarding Learning Experience Design in AI-integrated gamified learning environments.

Literature review

Awareness of Learning Experience Design (LxD) in AI-Integrated Gamified Learning Environments

Learning Experience Design (LxD) has emerged as a learner-centered approach that combines instructional design principles with user experience, engagement, and technology integration (Schmidt &huang, 2022). Within AI-integrated gamified learning environments, LxD focuses on designing meaningful, personalized, and interactive learning experiences that promote learner motivation and achievement (Bolaji et al., 2025). Recent studies in Nigeria indicate that teachers' awareness of innovative digital pedagogies remains a significant predictor of technology adoption. Victoria and Masalachi (2025) found that biology teachers in Niger State demonstrated varying levels of awareness regarding technology-enhanced instructional strategies, suggesting that awareness is a prerequisite for effective implementation of emerging educational technologies. Similarly, Awofala et al. (2025) reported that Nigerian science, technology, and mathematics teachers' adoption of educational AI tools was significantly influenced by their knowledge and understanding of AI applications in teaching and learning. Teachers who possessed greater awareness of AI capabilities were more willing to integrate these tools into classroom instruction (Owolarafe et al., 2024).

Furthermore, awareness of LxD is particularly important in biology education because the subject often involves abstract concepts that benefit from interactive visualization and personalized learning pathways (Ekanem & Ajayi, 2025). The increasing prominence of AI in education has also contributed to growing interest in LxD among educators. Successful integration of generative AI into educational practice requires teachers to possess awareness not only of AI tools but also of pedagogical design frameworks that support meaningful learning experiences (Zhai, 2025) Studies suggest that teachers who understand the principles of engagement, personalization, feedback, and interactivity are more likely to design effective learning experiences capable of improving student outcomes (Rachmad, 2023)..

Teachers' Use of AI-Integrated Gamified Strategies in Teaching Biology Concepts

The use of gamification in biology instruction has gained increasing attention due to its potential to improve learner engagement, motivation, and academic performance Owolarafe et al., 2024 : Widarbowo et et al., 2023). Gamification involves the application of game elements such as points, badges, levels, challenges, and rewards in non-game learning contexts (Jamil et al., 2024). In Nigeria, Udeani and Akhigbe (2020) demonstrated that gamified biology instruction significantly enhanced students' learning outcomes across individualized, competitive, collaborative, and cooperative learning modes. Thu, gamification can effectively support biology teaching when appropriately designed and implemented.

The emergence of AI technologies has expanded the capabilities of gamified learning environments by enabling adaptive feedback, intelligent tutoring, personalized challenges, and automated assessment (Abdulmumin et al., 2025). Recent Nigerian studies indicate that educators increasingly recognize the instructional value of AI-enhanced teaching tools (Jimba et al., 2024).

Awofala et al. (2025) found that teachers' actual use of AI tools depended on perceived usefulness, ease of use, and institutional support. Likewise, Abdulkareem (2025) reported positive integration of AI tools among pre-service teachers, particularly for lesson preparation, content generation, and personalized learning support.

Components of Learning Experience Design Applied by Biology Teachers in AI-Integrated Gamified Environments

LxD emphasizes the creation of learning experiences that are engaging, interactive, personalized, and supported by timely feedback. These components are particularly relevant within AI-integrated gamified learning environments because they directly influence learner motivation and achievement (Bolaji et al., 2025) Engagement refers to the extent to which learners are cognitively, emotionally, and behaviorally involved in learning activities. (Lackey, 2022). Gamification research consistently shows that game elements such as challenges, rewards, and progression systems increase learner engagement (Siregar, 2026). Gamification promotes active participation and sustained motivation in science education by creating meaningful and enjoyable learning experiences. (Olamoyegun &Ola-Adeniji , 2025)

Interactivity is another essential component of LxD. AI-enhanced learning systems enable dynamic interactions between learners, content, and instructional systems through simulations, adaptive questioning, intelligent tutoring, and collaborative activities (Wang & Huang, 2025) . Human-centered AI research emphasizes that meaningful interaction between users and educational technologies enhances learning effectiveness and trust in AI-supported systems (Chen et al, 2020). When teachers incorporate interactive features into biology instruction, students are better able to explore complex scientific concepts and construct knowledge through active participation.

Feedback represents a critical element of both gamification and LxD. AI technologies can provide immediate, personalized, and data-driven feedback that supports learner progress (Jimba et al, 2024). AI-powered educational systems facilitate continuous monitoring of learner performance and enable adaptive instructional responses(toAbdulmumin,2025). Gamification literature similarly highlights the importance of instant feedback in maintaining learner motivation and guiding improvement (Owolarafe et al., 2024). Personalized feedback allows students to identify learning gaps and make appropriate adjustments to their learning strategies.

Personalization refers to adapting learning experiences to learners' individual needs, preferences, and abilities (Sunday et al., 2025). AI technologies are particularly effective in supporting personalized learning because they analyze learner data and recommend suitable learning pathways. Recent evidence from Nigerian secondary school education indicates that students perceive AI-driven adaptive learning as beneficial for addressing individual learning needs and improving educational outcome (Jimba et al, 2024). Personalized learning experiences are especially valuable in biology education, where students often differ in prior knowledge, learning pace, and conceptual understanding.

Teachers' Perceptions of the Effectiveness of AI-Integrated Gamified Learning Environments

Teachers' perceptions play a critical role in determining the successful implementation of innovative instructional approaches. Within AI-integrated gamified learning environments, teachers' perceptions are often shaped by their beliefs regarding usefulness, ease of use, student engagement, and instructional effectiveness (Owolarafe et al,. 2024). Awofala et al. (2025) found that perceived usefulness significantly predicted Nigerian science, technology, and mathematics teachers' intention to adopt educational AI tools, suggesting that positive perceptions are essential for technology integration.

Studies on AI integration in Nigerian education have revealed that learners and educators perceive AI-supported instructional systems as valuable for enhancing learning outcomes, increasing engagement, and facilitating individualized instruction (Abdulkareem,2025 :. Abubakar et al. 2024 ; Owolarafe et al., 2025) Thus, educators andt students perceived AI integration as beneficial for improving learning effectiveness and supporting academic achievement, indicating that AI-enhanced pedagogies are generally welcomed when they address learners' educational needs.

Within biology education, gamified learning environments are often perceived as effective because they increase motivation, promote active participation, and facilitate understanding of abstract scientific concepts (Owolarafe et al., 2024). Research on digital learning systems in biology instruction indicates that teachers appreciate technology-enhanced environments that provide immediate feedback, adaptive learning pathways, and opportunities for collaborative learning (Bolaji et al., 2025). Moreover, AI-powered gamification enables personalized learning experiences through intelligent recommendations and adaptive challenges, which can improve learner engagement and academic performance.

Challenges Faced by Biology Teachers in Implementing Learning Experience Design within AI-Integrated Gamified Learning Environments

Despite the growing interest in AI-integrated gamified learning environments, several challenges continue to hinder effective implementation among Nigerian teachers. One major challenge is inadequate technological infrastructure (Bolaji et al., 2025). Many schools experience limited access to computers, internet connectivity, reliable electricity supply, and digital learning resources (Onyema 2020).. Such infrastructural deficiencies restrict teachers' ability to implement AI-supported instructional strategies and gamified learning activities effectively. Studies examining AI integration in Nigerian educational institutions consistently identify inadequate infrastructure as a major barrier to successful implementation (Owowlarafe et al., 2024 : Jimba et al 2024,.). Resistance to change is another challenge frequently reported in educational technology research (Jimba et al., 2024). Some teachers remain hesitant to adopt innovative approaches due to uncertainty, fear of technology, or preference for traditional instructional methods

Another significant challenge is insufficient teacher competence and professional development. Effective implementation of Learning Experience Design requires educators to possess competencies in instructional design, educational technology, AI literacy, and gamification principles (Tawfik et al., 2024:,Zhai ,2025). Findings revealed that many Nigerian educators recognize the potential of AI for improving instruction but require further professional development to understand how AI can be embedded within learner-centered experiences (Ekanem 7 Ajayi, 2025: Sunday et al., 2025: Abdulkareem,2025). Jimba et al. (2024) found that although biology teachers demonstrated awareness of generative AI tools, their actual utilization was constrained by inadequate training and limited technical expertise. Similarly, Awofala et al. (2025) observed that teachers' adoption of educational AI tools was influenced by their confidence, knowledge, and readiness to use such technologies in classroom settings.

Influence of Teaching Experience on the Adoption of Learning Experience Design in AI-Integrated Gamified Environments

Teaching experience has long been recognized as an important factor influencing educators' adoption of instructional innovations. Experienced teachers often possess extensive pedagogical knowledge and classroom management skills, which may facilitate the integration of new instructional approaches (Madu-Nwaigwe., 2024). However, research on educational technology adoption suggests that the relationship between teaching experience and technology integration is complex and sometimes contradictory (Abdulraheem et al., 2025). While experienced teachers may possess stronger pedagogical foundations, less experienced teachers often demonstrate greater technological confidence and willingness to experiment with emerging technologies.

Recent studies in Nigeria indicate that digital competence and technological readiness significantly influence educators' adoption of AI technologies (Abdulraheem et al., 2025). Teachers' behavioral intention to adopt educational AI tools was strongly influenced by factors such as self-efficacy, perceived usefulness, and technological readiness rather than demographic variables alone (Awofala et al. 2025). This suggests that teaching experience may affect adoption indirectly through its influence on teachers' confidence, pedagogical beliefs, and willingness to engage in professional training.. Abubakar and Onasanya (2025) reported that lecturers with stronger digital competencies and more positive attitudes toward AI were more likely to integrate AI technologies into teaching regardless of years of experience.

Therefore, there is a need to investigate Learning Experience Design in AI-integrated gamified learning environments, particularly from the perspective of secondary school biology teachers in Kwara state, Nigeria. Understanding teachers' awareness, utilization, perceptions, and challenges will provide valuable insights for improving instructional practices, informing educational policies, and guiding professional development initiatives aimed at enhancing the integration of emerging technologies in science education

Purposes of the Study

The main purpose of this study is to examine Learning Experience Design in an AI-Integrated Gamified Learning Environment for Secondary School Biology Teachers in Kwara state, Nigeria. Specifically, the study seeks to:

- Assess the level of awarenes of secondary school biology teachers about Learning Experience Design (LxD) in AI-integrated gamified learning environments.
- Examine the extent of teachers' use of AI-integrated gamified strategies in teaching biology concepts.
- Identify the components of learning experience design (engagement, interactivity, feedback, personalization) applied by biology teachers in AI-integrated gamified environments.
- Determine teachers' perceptions of the effectiveness of AI-integrated gamified learning environments in enhancing biology teaching and learning.
- Investigate the challenges faced by biology teachers in implementing LxD within AI-integrated gamified learning environments.
- Examine how Biology teachers teaching experience influence the adoption of LxD in AI-integrated gamified environments.

Five Research Questions

What is the level of awareness of secondary school biology teachers about Learning Experience Design in AI-integrated gamified learning environments?

To what extent do secondary school biology teachers use AI-integrated gamified strategies in teaching biology?

What components of Learning Experience Design are applied by biology teachers in AI-integrated gamified learning environments?

What are the perceptions of biology teachers regarding the effectiveness of AI-integrated gamified learning environments?

What challenges do secondary school biology teachers face in implementing Learning Experience Design in AI-integrated gamified learning environments?

Null Hypothesisz

H_{01}: There is no significant difference in the adoption of learning experience design in AI-integrated gamified environment based on teachers' years of teaching experience.

Methodology

This is a descriptive cross-sectional survey design employed examine Learning Experience Design in an AI-Integrated Gamified Learning Environment for Secondary School Biology Teachers in

Kwara state, Nigeria. The population of the study is made up of all secondary school Biology teachers in the Kwara state which is 596. . The sample size of 365 was determined using Cohen et al.'s (2018) sample size formula. To ensure the validity and reliability of the instrument, the Content validity was established through the review of experts and specialists in educational technology and measurement. A pilot test was conducted with 30 secondary school teachers outside the main study sample to refine item clarity and structure. Feedback led to minor revisions in-wording to ensure contextual appropriateness. Reliability was confirmed through Cronbach's alpha analysis with a *value* of 0.85 at a 0.05 significance level,

indicating the instrument was reliable. Data were collected from secondary school biology teachers using a researcher-designed questionnaire. Descriptive statistics of mean and standard deviation were employed for research questions while inferential statistics (ANOVA) was used to test hypothesis at 0.05 level of significance

Results and Discussions

Research Question 1: What is the level of awareness of secondary school biology teachers about Learning Experience Design (LxD) in AI-integrated gamified learning environments?

Table 1: Secondary school Biology teachers' level of awareness Learning Experience Design (LxD) in AI-integrated gamified learning environments

Statement	N	Mean	SD	Remark
I am familiar with the concept of Learning Experience Design (LxD) in education	234	2.97	0.83	High
I understand how AI can be integrated into gamified learning environments	234	3.03	0.79	High
I am aware of digital tools that support gamified biology instruction.	234	2.99	0.42	High
I have received training or professional development on AI-integrated learning approaches.	234	3.03	0.79	High
I understand how LxD principles can improve students' engagement in biology.	234	3.00	0.45	High

The findings revealed that secondary school biology teachers demonstrated a high level of awareness of Learning Experience Design (LxD) in AI-integrated gamified learning environments. This is evident from the mean ratings of the items, which ranged from 2.97 to 3.03, exceeding the decision benchmark of 2.50. The results suggest that the respondents are familiar with the concept

of LxD and possess adequate understanding of how artificial intelligence can be integrated into gamified learning environments to enhance biology instruction (Schmidt &huang, 2022).
The high mean scores recorded for awareness of AI integration and digital tools for gamified instruction indicate that teachers are increasingly exposed to emerging educational technologies and innovative pedagogical approaches. The finding further implies that biology teachers in secondary schools in Kwara state are becoming more conscious and aware of the relevance of learner-centered instructional design strategies in improving students' engagement and learning outcomes (Owolarafe et al., 2024)..

Research Question 2:To what extent do secondary school biology teachers use AI-integrated gamified strategies in teaching biology concepts?

Table 2: Extent of secondary school biology teachers use AI-integrated gamified strategies in teaching biology concepts

S/N	Statement	N	Mean	SD	Remark
1	I use gamified activities (e.g., quizzes, badges, points) when teaching biology.	234	2.98	0.92	High
2	I incorporate AI-based tools (e.g., chatbots, adaptive apps) in my biology lessons.	234	2.74	0.90	High
3	I design biology lessons that combine AI tools with game elements	234	2.71	0.59	High
4	I frequently use digital platforms to create interactive biology learning experiences.	234	2.75	0.99	High
5	I encourage students to engage with AI-supported gamified learning tasks.	234	2.75	0.99	High

The results showed that biology teachers moderately utilized AI-integrated gamified strategies in teaching biology, as reflected by the mean scores ranging from 2.71 to 2.98. The respondents agreed that they employ gamified activities such as quizzes, badges, and points during instruction and also make use of digital platforms to create interactive learning experiences, Udeani and Akhigbe (2020.

However, the comparatively lower mean scores on the use of AI-based tools and the design of lessons combining AI with gamification suggest that although teachers are aware of these technologies, their practical integration into classroom instruction is still at a developing stage. This finding may be attributed to inadequate training, limited technological resources, or insufficient technical competence in the use of advanced AI-supported instructional tools (Owolarafe et al., 2024).

Overall, the result implies that while teachers have begun integrating gamified instructional approaches into biology teaching, the adoption of fully AI-integrated gamified strategies remains moderate and requires further institutional support and professional development (Awofala et al., 2025).

Research Question 3: What components of Learning Experience Design are applied by biology teachers in AI-integrated gamified learning environments?

Table 3: components of Learning Experience Design are applied by biology teachers in AI-integrated gamified learning environments

Statement	N	Mean	SD	Remark
I design biology lessons that actively engage students in problem-solving activities.	234	3.06	0.64	Agree
I provide immediate feedback to students using digital or AI tools	234	2.97	0.81	Agree
I personalize biology learning activities to meet students' individual needs	234	2.96	0.80	Agree
I incorporate interactive elements (e.g., simulations, games) into my lessons	234	3.14	0.80	Agree
I structure lessons to ensure meaningful and enjoyable learning experiences	234	2.74	0.70	Agree

The findings indicated that biology teachers applied several essential components of Learning Experience Design in their instructional practices. The mean scores, which ranged from 2.74 to 3.14, revealed that teachers commonly incorporated interactive learning elements, engaged students in problem-solving activities, provided immediate feedback through digital tools, and personalized learning activities to meet students' needs (Bolaji et al., 2025).

The highest mean score was recorded for the incorporation of interactive elements such as simulations and games, suggesting that teachers recognize the importance of active learner participation in promoting meaningful learning experiences. The findings further indicate that teachers are gradually adopting learner-centered instructional strategies that align with the principles of Learning Experience Design (Wang & Huang, 2025).

This result implies that biology teachers are making deliberate efforts to create engaging and enjoyable learning environments capable of enhancing students' participation, motivation, and understanding of biology concepts through AI-supported gamified instruction (Chen et al, 2020).

Research Question 4: What are the perceptions of biology teachers regarding the effectiveness of AI-integrated gamified learning environments?

Table 4: Perceptions of biology teachers regarding the effectiveness of AI-integrated gamified learning environments

S/N	Statement	N	Mean	SD	Remark
1	AI-integrated gamified learning improves students' understanding of biology concepts	234	3.06	0.64	Agreed
2	Gamified learning environments increase students' motivation to learn biology	234	3.21	0.47	Agreed
3	AI tools enhance the quality of teaching and learning in biology	234	2.94	0.72	Agreed
4	Learning Experience Design makes biology lessons more engaging and interactive.	234	3.22	0.45	Agreed
5	AI-integrated gamification leads to better student learning outcomes in biology	234	3.06	0.50	Agreed

The findings revealed that biology teachers held positive perceptions regarding the effectiveness of AI-integrated gamified learning environments. The mean scores ranged from 2.94 to 3.22, indicating strong agreement among respondents that AI-integrated gamification improves students' understanding of biology concepts, increases motivation to learn, enhances lesson engagement, and promotes better learning outcomes (Owolarafe et al., 2025).

Particularly, the high mean ratings for increased student motivation and lesson engagement suggest that teachers perceive gamified instructional environments as capable of making biology teaching more interactive, stimulating, and learner-centered. The respondents also acknowledged the role of AI tools in improving the quality of teaching and learning processes (Abdulkareem,2025).

The implication of this finding is that teachers generally view AI-integrated gamified learning as an effective pedagogical approach capable of transforming traditional biology instruction into more engaging and outcome-driven learning experiences (Owolarafe et al., 2024)..

Research Question 5: What challenges do secondary school biology teachers face in implementing Learning Experience Design in AI-integrated gamified learning environments?

Table 5: Challenges secondary school biology teachers face in implementing Learning Experience Design in AI-integrated gamified learning environments

S/N	Statement	N	Mean	Std. Deviation
1	Lack of adequate training limits my use of AI-integrated gamified learning	234	3.18	0.88
2	Insufficient technological resources hinder my implementation of LxD	234	3.29	0.63
3	Poor internet connectivity affects my use of AI tools in teaching biology.	234	3.30	0.74
4	Time constraints make it difficult to design gamified learning experiences	234	3.37	0.66
5	Students' limited access to digital devices affects implementation of AI-based learning.	234	3.33	0.60

The findings identified several major challenges confronting teachers in the implementation of Learning Experience Design within AI-integrated gamified learning environments. The mean scores, which ranged from 3.18 to 3.37, indicate strong agreement among respondents that inadequate training, insufficient technological resources, poor internet connectivity, time constraints, and limited student access to digital devices constitute serious barriers to effective implementation (Bolaji et al., 2025 :Owolarafe et al., 2024)..

The highest mean score was associated with time constraints in designing gamified learning experiences, indicating that teachers perceive the preparation and integration of AI-supported gamified instruction as time demanding. Similarly, poor internet connectivity and inadequate technological infrastructure were identified as significant obstacles that limit the effective use of AI tools in biology instruction (Sunday et al., 2025: Onyema, 2020) .

These findings imply that despite the positive awareness and perception of AI-integrated gamified learning, infrastructural and technical limitations continue to hinder its successful implementation in secondary schools.

Hypothesis Testing

H_{01}: There is no significant difference in the adoption of learning experience design in AI-integrated gamified environment based on teachers' years of teaching experience.

	N	Mean	Std. Deviation

0-5 years	53	2.41	0.61
6-10 years	31	2.94	0.05
11-15 years	56	2.66	0.45
16 years and above	94	3.25	0.37
Total	234	2.88	0.55

ANOVA

Total Adoption					
	Sum of Squares	Df	Mean Square	F	p-value
Between Groups	27.446	3	9.149	48.474	0.000
Within Groups	43.409	230	0.189		
Total	70.856	233			

Since $p<0.05$ the null hypothesis was rejected. Thus, there was a significant difference in teachers' adoption of learning experience design based on teaching experience

The hypothesis was tested using Analysis of Variance (ANOVA). The result revealed a significant difference in the adoption of Learning Experience Design based on teachers' years of teaching experience, as indicated by the obtained F-value of 48.474 and a p-value of 0.000, which is less than the 0.05 level of significance. Consequently, the null hypothesis was rejected. This indicates that teachers' teaching experience significantly influences their adoption of Learning Experience Design in AI-integrated gamified learning environments.

Further examination of the group means scores showed that teachers with 16 years and above teaching experience recorded the highest mean adoption score (Mean = 3.25), whereas teachers with 0–5 years teaching experience recorded the lowest mean score (Mean = 2.41). This finding suggests that more experienced teachers are more likely to adopt Learning Experience Design practices in AI-integrated gamified environments than their less experienced counterparts (Madu-Nwaigwe., 2024). The result may be attributed to the fact that experienced teachers have had greater exposure to pedagogical innovations, classroom management strategies, and professional development opportunities that enhance their capacity to integrate emerging technologies into instructional practices.

Conclusions

This study concluded that secondary school biology teachers in Kwara State possess a high level of awareness of Learning Experience Design (LxD) and understand the relevance of AI-integrated gamified learning environments for enhancing biology instruction. The findings further revealed that although teachers moderately utilize AI-integrated gamified strategies, the practical integration of AI tools into classroom instruction remains limited. Biology teachers were found to apply key components of Learning Experience Design, including learner engagement, personalization, interactive learning activities, and feedback mechanisms. The teachers also demonstrated positive perceptions regarding the effectiveness of AI-integrated gamified learning in improving students' motivation, engagement, understanding, and learning outcomes. However, several challenges, such as inadequate training, insufficient technological resources, poor internet connectivity, time constraints, and limited access to digital devices, hinder effective implementation. Additionally, teaching experience significantly influenced the adoption of Learning Experience Design, with more experienced teachers demonstrating higher levels of adoption than less experienced teachers.

Recommendations

Based on the findings of the study, the following recommendations are made:

Professional development programmes should be organized regularly by educational authorities to equip biology teachers with practical skills for integrating AI tools and Learning Experience Design principles into gamified learning environments.

Government and school administrators should provide adequate technological infrastructure, including computers, digital devices, stable internet connectivity, and AI-supported educational software, to facilitate effective implementation of AI-integrated gamified learning.

Teacher education institutions and professional bodies should incorporate Learning Experience Design and AI-integrated pedagogical approaches into pre-service and in-service teacher training programmes.

Schools should encourage collaborative lesson planning and mentoring programmes, where experienced teachers can support less experienced teachers in adopting Learning Experience Design practices and AI-integrated gamified instructional strategies.

Educational policymakers should develop policies and frameworks that promote the integration of AI and gamification into secondary school science education to enhance teaching effectiveness and student learning outcomes.

School management should provide adequate time and institutional support for teachers to design, develop, and implement AI-integrated gamified learning experiences.

Efforts should be made to improve students' access to digital learning devices and internet services, particularly in underserved schools, to ensure equitable participation in AI-supported learning activities.

Further studies should be conducted in other subject areas and geographical locations to validate and extend the findings of this study on Learning Experience Design in AI-integrated gamified learning environments.

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INFLUENCE OF SECONDARY SCHOOL BIOLOGY TEACHERS' DEMOGRAPHIC FACTORS ON INFORMATION AND COMMUNICATION TECHNOLOGY COMPETENCE LEVEL IN NORTH-CENTRAL, NIGERIA

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Abstract

This study examined the influence of secondary school Biology teachers' demographic factors on Information and Communication Technology (ICT) competence level in North-Central, Nigeria. The study was guided by one research question and two research hypotheses. A descriptive research design using a cross-sectional survey approach was adopted for the study. The population comprised 1,929 public senior secondary school Biology teachers across six states and the Federal Capital Territory (FCT) in North-Central Nigeria. A sample of 696 Biology teachers was selected using a multi-stage sampling procedure involving stratified and proportional sampling techniques. A researcher-designed questionnaire titled Biology Teachers' Information and Communication Technology Competence Questionnaire (BTICTCQ) was used for data collection. The instrument was validated by experts and yielded a Cronbach's Alpha reliability coefficient of 0.90. Descriptive statistics, including frequency counts, percentages, and mean, were used to answer the research question, while independent samples t-test and one-way Analysis of Variance (ANOVA) were used to test the hypotheses at the 0.05 level of significance. The study revealed that Biology teachers in

secondary schools in North-Central Nigeria possess a low level of ICT competence. The findings further revealed a significant difference between male and female Biology teachers' ICT competence level. The study also established that academic qualification significantly influences Biology teachers' ICT competence level. Based on the findings, the study recommended that regular ICT training and professional development programmes should be organised for Biology teachers, and education authorities should promote continuous professional development and advanced academic training to strengthen Biology teachers' ICT competence.

Keywords: Information and Communication Technology, Secondary School Biology Teachers, Demographic Factors, Competence Level, Influence

Introduction

Information and Communication Technology (ICT) has become an indispensable component of contemporary education, transforming the way teachers plan, deliver, and assess instruction. The demands of 21st century education require teachers to possess the knowledge and skills needed to integrate digital technologies into classroom practices in ways that improve students' learning experiences and outcomes (Zivave et al., 2025). In Biology education, ICT provides opportunities to simplify abstract concepts through multimedia presentations, animations, simulations, virtual laboratories, and other interactive digital resources that make learning more meaningful and engaging (Putri et al., 2024). The integration of these technologies supports inquiry-based learning, enhances learner participation, and enables teachers to create student-centred learning environments that foster critical thinking, collaboration, and problem-solving skills. Consequently, the effectiveness of ICT integration in Biology classrooms depends largely on the competence of teachers in selecting, adapting, and applying appropriate technological tools to achieve instructional objectives (Sabri et al., 2024).

ICT competence extends beyond the ability to operate computers or digital devices. It encompasses ICT literacy, digital communication, information management, content creation, and the pedagogical knowledge required to integrate technology effectively into teaching and learning activities (Ajani, 2024). Biology teachers with high ICT competence are better positioned to employ innovative instructional strategies such as blended learning, flipped classrooms, virtual experiments, and adaptive learning platforms that promote active student engagement and improve conceptual understanding (Khong et al., 2023). These competencies also enable teachers to design multimedia instructional materials, utilise online educational resources, conduct formative

assessments using digital tools, and provide personalised learning experiences for students with diverse learning needs (Marouf et al., 2024). As educational technologies continue to evolve, ICT competence has become an essential professional requirement for Biology teachers seeking to improve instructional quality and prepare learners for participation in a technology-driven society.

The level of ICT competence demonstrated by Biology teachers is influenced by several demographic characteristics that shape teachers' access to technology, professional experiences, and opportunities for continuous learning. Demographic factors such as gender, age, teaching experience, academic qualification, school ownership, and school location have been identified as variables capable of influencing teachers' confidence, exposure to digital technologies, and willingness to integrate ICT into classroom instruction (Onu & Chwukuemeka, 2024). Academic qualification may determine the depth of professional preparation received by teachers, while teaching experience can influence their adaptability to emerging educational technologies. Similarly, differences between public and private schools, as well as rural and urban locations, often create unequal opportunities for access to ICT infrastructure, internet connectivity, technical support, and professional development programmes (Owolabi & Adedayo, 2020). These demographic characteristics may therefore contribute to variations in ICT competence among Biology teachers.

In Nigeria, efforts have been made to promote ICT integration through educational policies ateacher development initiatives. However, the implementation of these policies remains uneven across schools because of disparities in infrastructure, electricity supply, internet availability, funding, and access to continuous professional training (Afolabi & Adelakun, 2021). These challenges are particularly evident in North-Central Nigeria, where differences in educational resources across states, school ownership, and geographical locations may influence teachers' opportunities to acquire and utilise ICT competencies. Although many Biology teachers recognise the importance of technology in improving instructional delivery, their ability to integrate ICT effectively into classroom practice is often constrained by institutional and personal factors beyond their control (Ajani & Govender, 2023). Consequently, understanding the demographic characteristics associated with ICT competence is essential for designing interventions that improve teachers' technological capabilities and strengthen Biology education.

Despite the growing emphasis on technology-enhanced teaching, evidence suggests that many secondary school Biology teachers continue to experience varying levels of ICT competence, limiting the effective integration of digital technologies into classroom instruction (Badmus, 2023). Existing studies have largely focused on teachers' access to ICT facilities, attitudes toward technology, or general ICT utilisation, with relatively limited attention given to how demographic characteristics influence Biology teachers' ICT competence, particularly within the North-Central region of Nigeria (Farhana et al., 2024). Differences associated with gender, academic qualification, teaching experience, school ownership, and school location remain insufficiently examined, creating uncertainty regarding the extent to which these factors contribute to variations in ICT competence among Biology teachers. Addressing this gap is important because a clearer understanding of these demographic influences can provide evidence for targeted teacher training, equitable resource allocation, and informed educational policies aimed at strengthening ICT competence and improving the quality of Biology instruction in secondary schools across North-Central Nigeria.

Purpose of the Study

The main purpose of this study is to examine the influence of secondary school biology teachers' demographic factors on information and communication technology competence level in North-Central, Nigeria. Specifically, the study seek to;

1. assessed the ICT competence level of Biology teachers in secondary schools in North-Central, Nigeria;
2. explored the potential differences between male and female secondary schools Biology teachers' ICT competence level in North-Central, Nigeria; and
3. find out the influence of academic qualifications on Biology teachers' ICT literacy level in secondary schools in North-Central Nigeria.

Research Questionnaire

1. What is the ICT competence level of Biology teachers in secondary schools in North-Central, Nigeria?

Research Hypotheses

H_{01}: There is no significant potential differences between male and female secondary schools Biology teachers' ICT competence level in North-Central, Nigeria.

H_{02}: Academic qualifications has no significant influence on Biology teachers' ICT competence level in secondary schools in North-Central, Nigeria.

Methodology

This study adopted a descriptive research design using a cross-sectional survey approach. The design was considered appropriate because it enabled the collection of data from Biology teachers without manipulating any variables and provided information on their Information and Communication Technology (ICT) competence level and demographic characteristics. The population comprised all public senior secondary school Biology teachers in North-Central Nigeria, totalling 1,929 teachers across Kwara, Niger, Nasarawa, Kogi, Plateau, and the Federal Capital Territory (FCT). Benue State was excluded because of insecurity, making data collection difficult. A sample of 696 Biology teachers was selected using a multi-stage sampling procedure. Stratified random sampling technique will be used to classified teachers according to academic qualification, while proportional sampling ensured adequate representation of respondents from each selected state and the FCT.

Data were collected using a researcher-designed questionnaire. Section A obtained respondents' demographic information, including gender, and academic qualification, while Section B measured ICT competence using four-point Likert response scales. The instrument was validated by the researcher's supervisor and three lecturers in the Department of Science Education, Al-Hikmah University, Ilorin. A pilot test involving 50 Biology teachers in selected public secondary schools in Oyo State was conducted outside the study area to establish the instrument's suitability. The instrument demonstrated good internal consistency with an overall Cronbach's Alpha reliability coefficient of 0.90. Approval for data collection was obtained through an official introduction letter issued by the Department of Science Education, Al-Hikmah University. The researcher, assisted by ten trained research assistants, administered the questionnaire to Biology teachers in the selected schools. Frequency counts and percentages

described demographic characteristics, while mean was used to answer the research questions. Independent samples t-test was used to test the hypotheses at the 0.05 level of significance.

Results

Table 1:

Distribution of Respondents Based on Gender

Gender	Frequency	Percentage
Male	445	63.90
Female	251	36.10
Total	**696**	**100.00**

The data in Table 1 shows that most of the Biology teachers surveyed were male, accounting for 63.9% of the participants, while 36.1% were female. This highlights a significant gender imbalance, with male teachers being much more common than their female counterparts. The total number of respondents, 696, represents a wide-ranging and diverse sample, suitable for evaluating ICT competence and skill level related to pedagogical practices in secondary schools across North-Central Nigeria.

Table 2:

Academic Qualification of the Respondents

Qualifications	Frequency	Percentage
Qualified	532	76.40
Moderately Qualified	90	12.90
Unqualified	74	10.60

The results in Table 2 shows that most Biology teachers surveyed, 76.4%, are qualified to teach the subject effectively, with qualifications including a B.Sc. Ed, B.Sc. with PGDE, HND with PGDE, M.Sc. Ed., M.Ed., and Ph.D. in Biology. Additionally, 12.9% are classified as semi-qualified, possessing NCE, which implies they have some training but may lack complete

credentials. The remaining 10.6% are unqualified, holding HND, B.Sc., or M.Sc., indicating a lack of formal training or certification in education needed for teaching Biology. While the findings highlight a mostly qualified teaching workforce, they also highlight the need for targeted training or professional development to address gaps among semi-qualified and unqualified teachers. Ensuring that all educators meet the required standards is vital for improving the quality of Biology instruction in secondary schools within North-Central Nigeria.

Research Question One: What is the ICT competence level of Biology teachers in secondary schools in North-Central, Nigeria?

Table 3:

ICT Competence Level of Biology Teachers in Secondary Schools in North-Central, Nigeria

SN	Items	Mean	SD
1.	I am proficient in using databases to organize and analyse biological data	1.82	0.76
2.	I can effectively utilise graphic design software to create visually engaging materials for biology instruction	1.91	0.83
3.	I can integrate ICT tools such as interactive whiteboards or digital microscopes into my biology lessons.	1.83	0.79
4.	I feel confident in my capacity to troubleshoot technical issues related to hardware or software during biology lessons.	1.90	0.79
5.	I possess advanced skills in using multimedia editing software (e.g., Adobe Creative Suite) to develop instructional materials for biology teaching.	1.99	0.83
6.	I can effectively use online platforms and learning management systems to deliver biology content and interact with students.	1.78	0.80

7.	I have received sufficient training and professional development opportunities to enhance my ICT skills specifically for biology instruction.	1.92	0.82
8.	I am capable of integrating emerging technologies such as virtual reality into my biology lessons.	1.93	0.79
9.	I actively seek out new ICT tools and resources to stay updated with advancements in technology relevant to biology education.	1.84	0.79
10.	I collaborate with my colleagues in professional networks to share expertise related to ICT integration in biology teaching.	1.86	0.79

The results in Table 3 indicate that Biology teachers in secondary schools in North-Central Nigeria possess a generally low level of ICT competence. The mean scores for all the ICT competence indicators ranged from 1.78 to 1.99, showing low proficiency across the measured skills. The highest mean score (1.99) was recorded for the use of multimedia editing software in developing instructional materials, while the lowest mean score (1.78) was obtained for the use of online platforms and learning management systems for teaching and student interaction. Overall, the findings reveal that Biology teachers have low ICT competence, highlighting the need for improved ICT training and professional development.

Research Hypothesis One: There is no significant potential differences between male and female secondary schools Biology teachers' ICT competence level in North-Central, Nigeria.

Table 4:

T-test of Significant Differences in ICT Competence Level of Biology Teachers in Secondary Schools in North-Central, Nigeria

Variable	Mean	SD	SE	df.	t (Cal.)	Sig. (2t.)
Competence	18.03	5.92	0.22	695	74.50	0.00
Gender	1.36	0.48	0.18			

The results of a t-test conducted to determine whether male and female biology instructors in secondary schools in North-Central Nigeria differ significantly in their ICT competence level are presented in Table 4. The gender mean is 1.36, and the mean ICT competency score is 18.03, with standard deviations of 0.48 and 5.92, respectively. The ICT competency standard error is 0.22, indicating variability among instructors' reading level. A calculated t-value of 74.50 and a p-value of 0.00 were obtained from the t-test. The null hypothesis (H03) is rejected since the p-value is below the 0.05 threshold. Overall, the results show that male and female biology teachers in North-Central Nigeria differ significantly in their ICT competence level.

Research Hypothesis Two: Academic qualifications has no significant influence on Biology teachers' ICT competence level in secondary schools in North-Central, Nigeria.

Table 5:

ANOVA of Significant Difference in ICT Competence Level of Biology Teachers in Secondary Schools based on Academic Qualification

Variable	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	1095.26	2	547.62	16.28	0.00
Within Groups	23316.98	693	33.64		
Total	24412.24	695			

The results presented in Table 5 shows the outcomes of an ANOVA test to determine if biology teachers' ICT competence level in North-Central Nigerian secondary schools vary according to their academic qualification. ICT competence level across different certification categories are compared in the analysis. The investigation revealed a significant difference between the groups, with a p-value of 0.00 and an F-value of 16.28. Since the p-value is less than the significance level of 0.05, the null hypothesis (H05) is rejected. These findings indicate that a teacher's level of ICT competence is significantly affected by their credentials. This indicates that teachers with different qualifications may show varying level of ICT competency, emphasising the importance of qualifications in shaping ICT skills. Further research could investigate which

specific qualifications are associated with higher ICT competence, which could inform professional development programmes aimed at enhancing teachers' ICT abilities.

Discussion

This study revealed that Biology teachers in secondary schools in North-Central Nigeria possess a low level of ICT competence, indicating the need for improved ICT training and professional development. This finding is consistent with Ajani and Govender (2023), who reported that many secondary school teachers in developing countries demonstrate inadequate ICT competence due to limited access to continuous professional development and insufficient technological resources. The finding also agrees with Hidayat et al. (2024), who found that Biology teachers' ICT competence remains relatively low because many educators lack adequate training and practical experience in integrating digital technologies into classroom instruction. The finding further aligns with Raza and Akhter (2024), who concluded that disparities in access to ICT facilities, professional development opportunities, and institutional support contribute to low ICT competence among teachers, thereby limiting the effective integration of technology into teaching and learning.

This study revealed that there is a significant difference between male and female Biology teachers in their ICT competence level in secondary schools in North-Central Nigeria. This finding is consistent with Onu and Chukwuemeka (2024), who reported that gender influences teachers' ICT competence because differences in technology exposure, access to digital resources, and professional development opportunities contribute to variations in ICT proficiency. The finding also agrees with Ata and Cevik (2020), who found that gender significantly affects teachers' confidence and competence in integrating ICT into classroom instruction. The finding further supports Cox and Graham (2020), who concluded that male and female teachers often demonstrate different levels of ICT competence due to variations in training opportunities, technological experience, and institutional support.

This study revealed that academic qualification has a significant influence on the ICT competence level of Biology teachers in secondary schools in North-Central Nigeria. This finding is consistent with Ajani (2024), who explained that teachers with higher academic qualifications are more likely to possess the pedagogical and technological knowledge required for effective ICT integration in classroom instruction. The finding also agrees with Ajani and Govender (2023), who

reported that teachers' academic qualifications significantly contribute to their ICT competence because higher qualifications are often associated with greater exposure to technology-related training and professional development. The finding further aligns with Bebell and Kay (2019), who concluded that teachers with stronger educational backgrounds demonstrate higher levels of ICT competence and are more capable of integrating digital technologies effectively into teaching and learning activities.

Conclusion

The study concluded that Biology teachers in secondary schools in North-Central Nigeria generally possess a low level of ICT competence, indicating the need to strengthen their technological knowledge and skills for effective classroom instruction. The study also concluded that ICT competence differs significantly between male and female Biology teachers, suggesting that gender is associated with variations in teachers' ICT competence. In addition, academic qualification significantly influences Biology teachers' ICT competence, implying that teachers with different educational qualifications demonstrate varying levels of ICT competence. Thus, the findings indicate that improving teachers' ICT competence through continuous professional development, equitable training opportunities, and support across all qualification categories is essential for enhancing the integration of technology into Biology teaching.

Recommendations

1. Regular ICT training and professional development programmes should be organized for Biology teachers to improve their ICT competence and strengthen their ability to integrate technology effectively into Biology instruction.
2. Equal access to ICT training, mentoring, and technological resources should be provided for both male and female Biology teachers to minimize gender-related differences in ICT competence.
3. Education authorities should encourage continuous professional development and advanced academic training for Biology teachers through workshops, in-service training, postgraduate studies, and ICT certification programmes to enhance their ICT competence regardless of their academic qualifications.

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DIGITAL SKILL LEVEL AND THE USE OF ONLINE COLLABORATIVE LEARNING TOOLS FOR LEARNING ACTIVITIES AMONG UNDERGRADUATE MATHEMATICS STUDENTS IN UNIVERSITIES IN KWARA STATE

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ABSTRACT

This study examined the digital skill level and the use of online collaborative learning tools for learning activities among undergraduate mathematics students in universities in Kwara State. The study was guided by two research questions and one research hypothesis. The descriptive survey of the correlational type was adopted for the study. The population comprised undergraduate mathematics students in the selected universities in Kwara State, with a target population of 96,457 students. A sample size of 383 undergraduate mathematics students was selected using simple random sampling technique to select the respondents from the three purposively selected universities. A researcher-designed questionnaire titled: Digital Skill Level and Use of Online Collaborative Learning Tools Questionnaire (DSLUOCLTQ) was used for data collection. Descriptive statistics such as mean was used to answer the research questions, while inferential statistics such as PPMC was used to test the research hypothesis at 0.05 level of significance. The study revealed that undergraduate mathematics students possess a high level of digital skills for the effective use of online collaborative learning tools. The study also revealed that undergraduate mathematics students make use of online collaborative learning tools for learning activities to a high extent. Furthermore, the findings revealed a significant relationship between digital skill level and the use of online collaborative learning tools for learning activities among undergraduate mathematics students. Based on the findings, it was recommended that universities should

strengthen students' digital skills through regular training and enhance the integration of online collaborative learning tools into mathematics teaching and learning.

Keywords: Digital Skill, Use, Online Collaborative Learning Tools, Learning Activities, Undergraduate, Mathematics Students, Universities in Kwara State

Introduction

Technology integration in mathematics education has transformed the way undergraduate students engage with learning activities by expanding opportunities for interaction, visualization, and collaborative problem solving. The incorporation of digital technologies into mathematics instruction supports active learning environments where students can explore mathematical concepts through interactive platforms rather than relying solely on traditional lecture methods. Mathematics learning increasingly requires students to communicate ideas, justify procedures, and solve complex problems collaboratively using digital environments that facilitate knowledge construction and immediate feedback (Bond et al., 2024). Learning experiences that combine technology with collaborative pedagogies strengthen conceptual understanding and improve students' engagement with mathematical tasks. Such environments also encourage independent learning while maintaining meaningful peer interaction through digital platforms that support synchronous and asynchronous communication (Farrokhnia et al., 2024). Universities therefore continue to incorporate technology-enhanced instructional approaches into mathematics education because digital learning environments promote flexibility, participation, and learner-centered instruction (Crompton & Burke, 2023).

The emphasis on collaborative learning in mathematics education has increased because mathematical understanding develops more effectively when learners exchange ideas, defend solutions, and collectively construct knowledge. Collaborative learning enables undergraduate mathematics students to solve authentic problems through discussion, peer explanation, and shared reasoning, thereby strengthening higher-order thinking and analytical skills. Online collaborative learning tools provide digital spaces where learners can communicate, edit documents simultaneously, organize group projects, and participate in virtual discussions regardless of geographical location (Jeong et al., 2019). These tools include shared document platforms, virtual meeting applications, digital whiteboards, learning management systems, and collaborative communication applications that support cooperative learning activities. The integration of such

technologies into mathematics instruction enhances students' opportunities to engage in collaborative inquiry and improves the quality of interaction during mathematical investigations (Bond et al., 2024). Digital collaboration also promotes continuous engagement beyond the physical classroom by enabling students to work together on assignments, projects, and problem-solving activities at their convenience (Farrokhnia et al., 2024).

The effectiveness of online collaborative learning tools in mathematics education depends substantially on the digital skill level of learners. Digital skills refer to the knowledge and abilities required to confidently access, evaluate, create, manage, and communicate information using digital technologies in different learning contexts. Undergraduate mathematics students require operational, information management, communication, collaboration, and problem-solving skills to maximize the educational benefits of collaborative technologies (van Laar et al., 2017). These competencies enable students to navigate digital platforms efficiently, participate actively in online discussions, and contribute meaningfully to collaborative mathematical tasks. Insufficient digital skills may reduce students' confidence in using collaborative technologies and limit their participation during group learning activities. Strong digital competencies therefore provide the foundation for effective engagement with online collaborative learning environments and contribute to improved learning experiences in mathematics education (Siddiq et al., 2024). Continuous development of students' digital capabilities has consequently become an essential objective of higher education institutions seeking to prepare graduates for technology-driven academic and professional environments (Crompton & Burke, 2023).

Online collaborative learning tools have become integral components of university mathematics education because they facilitate communication, resource sharing, and cooperative problem solving among students. Platforms such as shared online documents, virtual conferencing applications, collaborative whiteboards, and learning management systems enable learners to jointly develop mathematical solutions, exchange ideas, and receive immediate feedback from peers and instructors. These technologies encourage students to participate actively in mathematical discourse while promoting accountability for group learning outcomes (Bond et al., 2024). Mathematics courses involving proofs, computations, modelling, and statistical analysis particularly benefit from collaborative digital environments because they allow students to explain concepts, compare alternative solution methods, and collectively refine mathematical reasoning.

Appropriate utilization of these technologies also increases learning flexibility by enabling continuous collaboration beyond classroom hours and supporting blended or fully online learning arrangements (Farrokhnia et al., 2024). Effective implementation nevertheless depends on students possessing sufficient digital skills to use the available collaborative technologies efficiently (van Laar et al., 2017).

The use of online collaborative learning tools among undergraduate mathematics students extends beyond communication to include collaborative assignment completion, peer tutoring, project development, mathematical modelling, examination preparation, and resource exchange. Regular use of these technologies creates opportunities for students to learn from one another, improve mathematical communication, and strengthen conceptual understanding through continuous interaction. Mathematics learning increasingly requires collaborative exploration of complex problems that cannot always be addressed through individual study alone, making digital collaboration particularly valuable within university environments (Jeong et al., 2019). Frequent engagement with collaborative technologies also promotes self-directed learning by allowing students to access learning materials, monitor group progress, and participate in discussions at convenient times. Productive use of collaborative learning tools depends not only on institutional availability but also on students' ability to integrate these technologies meaningfully into their daily academic activities (Siddiq et al., 2024). Consequently, digital skill level is expected to influence how effectively undergraduate mathematics students utilize collaborative technologies for learning activities.

Online collaborative learning tools have become increasingly important in supporting interactive and learner-centered mathematics instruction, while adequate digital skills enable students to use these technologies effectively for communication, resource sharing, and collaborative problem-solving activities (Farrokhnia et al., 2024). Despite these advantages, the extent to which undergraduate mathematics students in universities in Kwara State possess the digital skills required to effectively utilize online collaborative learning tools for learning activities remains uncertain. Variations in students' digital skill levels may influence their ability to engage in collaborative mathematics learning, yet empirical evidence addressing this relationship within universities in Kwara State is limited. Existing studies have largely focused on technology adoption, artificial intelligence, or general digital learning in higher education, with relatively little

attention given to how students' digital skill levels relate to their use of online collaborative learning tools specifically for mathematics learning activities. This study therefore seeks to examine digital skill level and the use of online collaborative learning tools for learning activities among undergraduate mathematics students in universities in Kwara State.

Purpose of the Study

The main purpose of the study is to examine digital skill level and the use of online collaborative learning tools for learning activities among undergraduate mathematics students in universities in Kwara State. Specifically, this study seek to;

1. determine the digital skill level of undergraduate mathematics students in universities in Kwara State;
2. assess the extent of use of online collaborative learning tools for learning activities among undergraduate mathematics students in universities in Kwara State; and
3. find out the relationship between digital skill level and the use of online collaborative learning tools for learning activities among undergraduate mathematics students in universities in Kwara State.

Research Questions

1. What is the digital skill level of undergraduate mathematics students in universities in Kwara State?
2. What is the extent of use of online collaborative learning tools for learning activities among undergraduate mathematics students in universities in Kwara State?

Research Hypothesis

H_{01}: There is no significant relationship between digital skill level and the use of online collaborative learning tools for learning activities among undergraduate mathematics students in universities in Kwara State.

Methodology

This study adopted a descriptive survey research design of the correlational type to examine the relationship between digital skill level and the use of online collaborative learning tools for learning activities among undergraduate mathematics students in universities in Kwara State. The

design was considered appropriate because it enabled the collection of quantitative data from a large population without manipulating the study variables. The population of the study comprised all undergraduate mathematics students in selected universities in Kwara State. A sample size of 383 undergraduate mathematics students was determined using the Research Advisors (2006) sample size determination table at a 95% confidence level, a 5% margin of error and a target population of 96,457. Simple random sampling technique was used to select the respondents from the three purposively selected universities in Kwara State offering undergraduate mathematics programmes, to ensure that every undergraduate mathematics student had an equal chance of being selected in the study. Data were collected using a researcher-designed questionnaire titled: Digital Skill Level and Use of Online Collaborative Learning Tools Questionnaire (DSLUOCLTQ). The instrument consisted of Section A, which measured undergraduate mathematics students' digital skill level, and Section B, which measured the use of online collaborative learning tools for learning activities.

The questionnaire was validated for face and construct validity by experts in Science Education (Mathematics Education Programme), Faculty of Education, Al-Hikmah University, Ilorin, who examined the relevance, appropriateness, clarity, and adequacy of the items in relation to the objectives of the study. A pilot test involving 50 undergraduate mathematics students from a university outside Kwara State was conducted using the internal consistency method to determine the reliability of the instrument and to ensure that the questionnaire items were clear, understandable, and suitable without influencing the participants in the main study. The responses obtained from the pilot study were analyzed using Cronbach's Alpha, which yielded a reliability coefficient of 0.78, indicating that the instrument possessed satisfactory internal consistency. Data collection for the main study was carried out after obtaining permission from the relevant university authorities and the respondents. The completed questionnaires were retrieved immediately after administration for analysis. Mean was used to answer the research questions, while Pearson Product Moment Correlation (PPMC) was used to test the research hypothesis at the 0.05 level of significance.

Results and Discussion

Research Question One: What is the digital skill level of undergraduate mathematics students in universities in Kwara State?

Table 1: *Distribution of the Respondents on the Digital Skill Level of Undergraduate Mathematics Students*

QUESTIONNAIRE ITEMS	VH	H	L	VL	X	Std. D
What is your skill level in using online collaborative learning tools (e.g., Google Docs, Microsoft Teams, Zoom, or WhatsApp) for mathematics learning activities?	78	217	84	4	2.96	0.68
What is your skill level in creating, editing, and sharing mathematics learning documents through online collaborative learning tools?	77	197	93	16	2.88	0.81
What is your skill level in participating in virtual group discussions and online meetings for mathematics learning using online collaborative learning tools?	87	193	91	12	2.93	0.80
What is your skill level in locating, organizing, and managing mathematics learning resources using online collaborative learning tools?	65	197	109	12	2.82	0.79
What is your skill level in resolving minor technical problems encountered while using online collaborative learning tools for mathematics learning?	56	209	106	12	2.81	0.76

Source: Field Survey, (2026)

Table 1 showed the digital skill level of undergraduate mathematics students in universities in Kwara State. From Table 1, it was observed that the mean scores of all the questionnaire items were above 2.50, indicating that the respondents possessed a high level of digital skills required for the use of online collaborative learning tools for mathematics learning activities. Specifically, respondents reported a high skill level in using online collaborative learning tools such as Google Docs, Microsoft Teams, Zoom, or WhatsApp for mathematics learning activities ($\bar{X} = 2.96$, SD = 0.68). They also indicated a high skill level in participating in virtual group discussions and online meetings for mathematics learning ($\bar{X} = 2.93$, SD = 0.80) as well as in creating, editing, and sharing mathematics learning documents through online collaborative learning tools ($\bar{X} = 2.88$, SD = 0.81). Furthermore, respondents reported a high skill level in locating, organizing, and managing mathematics learning resources using online collaborative learning tools ($\bar{X} = 2.82$, SD = 0.79) and in resolving minor technical problems encountered while using online collaborative learning tools for mathematics learning ($\bar{X} = 2.81$, SD = 0.76). Thus, this study revealed that undergraduate mathematics students in universities in Kwara State possess a high level of digital skills for the

effective use of online collaborative learning tools, with the highest competence observed in the use of collaborative platforms for mathematics learning activities.

Research Question Two: What is the extent of use of online collaborative learning tools for learning activities among undergraduate mathematics students in universities in Kwara State?

Table 2:

Distribution of the Respondents on the Extent of Use of Online Collaborative Learning Tools for Learning Activities among Undergraduate Mathematics Students

QUESTIONNAIRE ITEMS	VHE	HE	LE	VLE	X	Std. D
To what extent do you use online collaborative learning tools for discussing mathematics concepts with your classmates?	25	222	112	24	2.65	0.70
To what extent do you use online collaborative learning tools for completing group assignments in mathematics courses?	31	196	126	30	2.60	0.75
To what extent do you use online collaborative learning tools for sharing mathematics learning materials and resources with other students?	36	191	133	23	2.63	0.74
To what extent do you use online collaborative learning tools to participate in virtual study groups for mathematics courses?	27	198	137	21	2.60	0.70
To what extent do you use online collaborative learning tools to prepare for mathematics tests and examinations with your classmates?	35	196	127	25	2.63	0.74

Source: Field Survey, (2026)

Table 2 showed the extent of use of online collaborative learning tools for learning activities among undergraduate mathematics students in universities in Kwara State. From Table 2, it was observed that the mean scores of all the questionnaire items were above the criterion mean of 2.50, indicating that the respondents use online collaborative learning tools to a high extent for their learning activities. Specifically, most respondents ($\bar{X}$ = 2.65, SD = 0.70) indicated that they use online collaborative learning tools for discussing mathematics concepts with their classmates. Respondents also reported using these tools for sharing mathematics learning materials and resources with other students ($\bar{X}$ = 2.63, SD = 0.74) and for preparing for mathematics tests and examinations with their classmates ($\bar{X}$ = 2.63, SD = 0.74). Furthermore, respondents indicated that they use online collaborative learning tools for completing group assignments in mathematics

courses ($\bar{X}$ = 2.60, SD = 0.75) and for participating in virtual study groups for mathematics courses ($\bar{X}$ = 2.60, SD = 0.70). Thus, this study revealed that undergraduate mathematics students in universities in Kwara State make use of online collaborative learning tools for learning activities to a high extent, with discussing mathematics concepts with classmates being the most frequently reported use.

Research Hypothesis One:

H_{01}: There is no significant relationship between digital skill level and the use of online collaborative learning tools for learning activities among undergraduate mathematics students in universities in Kwara State.

Table 3: *Summary of Pearson Product Moment Correlation between Digital Skill Level and the Use of Online Collaborative Learning Tools for Learning Activities among Undergraduate Mathematics Students*

Variables	N	Mean	SD	df	r-cal	Sig.	Remark
Digital Skill Level	383	14.31	2.68	381	0.531	0.000	Rejected
Use of Online Collaborative Learning Tools	383	16.58	2.17				

*Significant at P<0.05

Source: Field Survey, (2026)

Table 3 showed that the r-cal is 0.531 and the p-value is 0.000 which is lesser than 0.05 level of significance. Therefore, the null hypothesis which stated that "there is no significant relationship between digital skill level and the use of online collaborative learning tools for learning activities among undergraduate mathematics students in universities in Kwara State." is hereby rejected. Thus, this study revealed that there is significant relationship between digital skill level and the use of online collaborative learning tools for learning activities among undergraduate mathematics students in universities in Kwara State.

Summary of Findings

The data collected from the respondents was analyzed using Mean to answer the research questions, PPMC to test the research hypothesis. The following were the outcome of the findings:

1. This study revealed that undergraduate mathematics students in universities in Kwara State possess a high level of digital skills for the effective use of online collaborative learning tools, with the highest competence observed in the use of collaborative platforms for mathematics learning activities.
2. This study revealed that undergraduate mathematics students in universities in Kwara State make use of online collaborative learning tools for learning activities to a high extent, with discussing mathematics concepts with classmates being the most frequently reported use.
3. This study revealed that there is significant relationship between digital skill level and the use of online collaborative learning tools for learning activities among undergraduate mathematics students in universities in Kwara State.

Discussion of Findings

This study revealed that undergraduate mathematics students in universities in Kwara State possess a high level of digital skills for the effective use of online collaborative learning tools, with the highest competence observed in the use of collaborative platforms for mathematics learning activities. This finding is consistent with van Laar et al. (2017), who explained that digital skills are fundamental competencies that enable learners to effectively utilize digital technologies for communication, collaboration, information management, and problem solving in educational settings. The finding also agrees with Siddiq et al. (2024), who reported that university students with higher digital competence demonstrate greater confidence and effectiveness in using digital technologies for academic purposes. The high digital skill level observed in this study suggests that undergraduate mathematics students possess the competencies required to navigate online collaborative platforms and actively participate in technology-supported mathematics learning activities.

This study revealed that undergraduate mathematics students in universities in Kwara State make use of online collaborative learning tools for learning activities to a high extent, with discussing mathematics concepts with classmates being the most frequently reported use. This finding is in agreement with Bond et al. (2024), who noted that collaborative digital technologies have become integral to higher education by supporting communication, collaborative knowledge construction, and active student engagement in learning activities. The finding also supports Jeong et al. (2019), who found that computer-supported collaborative learning enhances students'

participation, interaction, and academic achievement in science, technology, engineering, and mathematics (STEM) education. The high level of use reported in this study indicates that undergraduate mathematics students increasingly rely on online collaborative learning tools to facilitate group discussions, complete assignments, exchange learning resources, and prepare for academic assessments.

This study revealed that there is a significant relationship between digital skill level and the use of online collaborative learning tools for learning activities among undergraduate mathematics students in universities in Kwara State. This implies that students with higher digital skill levels are more likely to make effective use of online collaborative learning tools for academic purposes than those with lower digital skill levels. This finding agrees with van Laar et al. (2017), who emphasized that digital competence serves as a key determinant of learners' ability to participate effectively in technology-enhanced learning environments. The finding is also consistent with Siddiq et al. (2024), who concluded that well-developed digital skills positively influence students' engagement with digital learning technologies and improve their ability to benefit from collaborative online learning environments. The significant relationship established in this study therefore underscores the importance of strengthening students' digital skills as a means of promoting greater utilization of online collaborative learning tools for mathematics learning activities in universities.

Conclusion

This study concluded that undergraduate mathematics students in universities in Kwara State possess a high level of digital skills required for effective participation in online collaborative learning activities. The study also established that the students make use of online collaborative learning tools to a high extent for discussing mathematics concepts, completing group assignments, sharing learning resources, participating in virtual study groups, and preparing for tests and examinations. Furthermore, the study concluded that digital skill level has a significant relationship with the use of online collaborative learning tools for learning activities. Therefore, enhancing students' digital skills is likely to promote greater utilization of online collaborative learning tools and improve collaborative learning experiences in mathematics education within universities in Kwara State.

Recommendations

Based on the findings of this study, the following recommendations were made:

1. Universities in Kwara State should organize regular digital skills training, workshops, and hands-on practical sessions for undergraduate mathematics students to further strengthen their competence in using online collaborative learning tools for mathematics learning activities.
2. Mathematics departments should encourage lecturers to integrate online collaborative learning tools into teaching, assignments, group projects, and classroom discussions in order to sustain and improve students' use of these tools for effective learning.
3. University management should invest in reliable digital infrastructure, including stable internet connectivity and access to appropriate collaborative learning platforms, while continuously improving students' digital skills to enhance the effective use of online collaborative learning tools for mathematics learning activities.

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A Companion or a Trustworthy Partner? Exploring the Influence of Students' Overreliance on Artificial Intelligence Tools

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Abstract

Abstract

The rapid adoption of artificial intelligence (AI) tools in higher education has transformed students' approaches to learning, information processing, and academic problem-solving. While AI applications increasingly function as learning assistants, their growing use raises critical questions about whether they serve as trustworthy cognitive partners that enhance learning or become sources of overreliance that weaken students' cognitive development. This study, titled "A Companion or a Trustworthy Partner? Exploring the Influence of Students' Overreliance on Artificial Intelligence Tools," examined students' perceptions of AI tools as cognitive companions, factors influencing AI reliance, the extension of cognitive abilities through AI, and the effects of overreliance on cognitive development. The study was anchored on the Extended Mind Theory, which explains how external tools can become extensions of human cognition when appropriately integrated into thinking processes. A quantitative cross-sectional survey design was adopted, involving 320 undergraduate students from public universities in South-West Nigeria. Data were collected using the AI Cognitive Companion and Overreliance Scale (AICCOS) and analysed using descriptive statistics. The findings revealed that students perceive AI tools as supportive cognitive companions that enhance understanding, academic assistance, and learning confidence. Accessibility, convenience, efficiency, and personalised support were identified as major factors influencing AI reliance. The findings further showed that AI tools extend students' cognitive abilities by supporting information retrieval, idea generation, and knowledge exploration. However, excessive dependence on AI was found to

pose risks to independent thinking, critical reasoning, creativity, and cognitive autonomy. The study concludes that AI should function as a trustworthy cognitive partner that complements human intelligence rather than replacing students' active engagement in learning.

Keywords: *Artificial intelligence, cognitive companion, trustworthy partner, overreliance, extended mind theory, cognitive development, higher education.*

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Introduction

Artificial intelligence (AI) tools, particularly generative AI applications such as ChatGPT, Google Gemini, and Microsoft Copilot, have become deeply embedded in the academic routines of university students across the globe. What began as a novelty for drafting text has evolved into a pervasive resource for brainstorming, summarising, problem solving, and even structuring entire assignments (Chan & Hu, 2023). For many students, these tools now occupy a role that resembles a study companion, one that is always available, non-judgmental, and capable of producing plausible answers within seconds. This shift raises a fundamental question for educational psychology and instructional design: are AI tools genuine extensions of students' cognitive faculties, or are they gradually substituting for the very mental effort that learning is meant to cultivate?

The Extended Mind Theory (EMT) proposed by Clark and Chalmers (1998) offers a compelling lens through which to examine this question. EMT argues that cognitive processes are not confined to the biological brain but can extend into external tools and artefacts that are reliably accessed and functionally integrated into a person's thinking. Under this framework, a student who consistently and appropriately uses an AI tool to organise ideas or verify facts may be exercising an extended form of cognition rather than abandoning cognitive effort altogether. However, the same theory implicitly raises the danger of overextension, wherein the external tool no longer complements internal cognitive processes but effectively replaces them, leaving the learner cognitively diminished when the tool is unavailable (Risko & Gilbert, 2016).

Emerging empirical evidence lends weight to this concern. Gerlich (2025) reported a significant negative correlation between frequent AI tool use and critical thinking scores among young adults, mediated by increased cognitive offloading. Similarly, Zhai et al. (2024), in a systematic review of studies on AI dialogue systems, found consistent evidence that overreliance on conversational AI diminishes students' capacity for independent analysis and memory retention, even as it improves short term task performance. These findings mirror earlier work by Sparrow et al. (2011), who demonstrated that easy access to searchable information alters what people choose to remember, a phenomenon often termed the Google effect. Against this backdrop, the present study investigates whether Nigerian undergraduate students perceive AI tools as trustworthy cognitive partners, what drives their reliance on these tools, and whether such reliance, when excessive, undermines the cognitive development that university education is designed to foster.

Despite a growing body of international literature on generative AI in higher education (Bhutoria, 2022; Kasneci et al., 2023; Zawacki Richter et al., 2019), empirical studies that simultaneously examine perception, the antecedents of reliance, cognitive extension, and the developmental costs of overreliance within a single integrated framework remain scarce, particularly in sub-Saharan African contexts. This study addresses that gap by providing an empirically grounded account of how AI tools function in the cognitive lives of undergraduate students.

University lecturers increasingly report that students submit assignments that are fluent but shallow, correctly formatted yet conceptually thin, a pattern many attributes to unmediated AI assistance (Farrokhnia et al., 2024). Institutions have responded inconsistently, with some banning AI tools outright and others cautiously integrating them into instruction, largely in the absence of empirical data on how students themselves experience these tools cognitively. Without understanding whether students treat AI as a companion that scaffolds thinking or as a substitute that replaces it, policy responses risk being either unnecessarily restrictive or dangerously permissive. This study was therefore designed to generate empirical evidence to inform that policy conversation.

Research Purpose

1. Explore students' perceptions of the role of artificial intelligence tools as cognitive companions in their learning experiences.
2. Examine the factors that influence students' reliance on artificial intelligence tools for academic learning.
3. Investigate how artificial intelligence tools extend students' cognitive abilities during the learning process.
4. Explore how overreliance on artificial intelligence tools influences students' cognitive development.

Research Questions

1. How do students perceive the role of artificial intelligence tools as cognitive companions in their learning experiences?

2. What factors influence students' reliance on artificial intelligence tools for academic learning?

3. How do artificial intelligence tools extend students' cognitive abilities?

4. How does overreliance on artificial intelligence tools influence students' cognitive development?

Literature Review

Theoretical Framework

This study is anchored on the Extended Mind Theory (EMT) proposed by Clark and Chalmers (1998), which challenges the traditional view that cognition is confined exclusively to processes occurring within the human brain. Clark and Chalmers (1998) argued that when an external resource is reliably available, easily accessible, and automatically endorsed once retrieved, it can function as a genuine constituent of a person's cognitive system rather than a mere aid to it. Their now classic thought experiment involving a notebook used by a person with memory impairment illustrated that external artefacts can play the same functional role as internal memory, provided the coupling between the person and the artefact is tight and trustworthy.

Applied to contemporary AI tools, EMT suggests that when students use AI applications to retrieve information, structure arguments, or check reasoning, they may be extending their cognitive system rather than abdicating it, provided the interaction remains reflective and the student retains critical oversight of the output (Bearman & Ajjawi, 2023). However, scholars applying EMT to digital technologies have cautioned that the theory presupposes an active, discerning user; when engagement becomes passive or uncritical, the extension collapses into substitution, and the cognitive benefits theorised by Clark and Chalmers (1998) give way to atrophy of the very faculties being offloaded (Risko & Gilbert, 2016). This tension between extension and substitution forms the conceptual backbone of the present study, guiding the operationalisation of both the cognitive companion construct and the overreliance construct.

AI Tools as Cognitive Companions in Learning

A growing body of research describes students' experience of AI tools in distinctly relational terms. Chan and Hu (2023), in a mixed methods study of university students in Hong Kong, found that a majority of respondents viewed generative AI as a supportive academic partner that reduced anxiety around writing and provided immediate, individualised feedback, functions traditionally associated with human tutors. Likewise, Kasneci et al. (2023) argued that large language models can act as always available dialogic partners that scaffold understanding through iterative questioning, provided students are guided to use them reflectively rather than extractively. These findings resonate with the companion framing embedded in the present study's title, suggesting that many students do not experience AI merely as a search tool but as an interactive presence in their learning process.

Factors Influencing Students' Reliance on AI Tools

Several studies have examined the antecedents of AI reliance among students. Bhutoria (2022), in a systematic review of personalised AI in education across the United States, China, and India, identified convenience, perceived accuracy, and time efficiency as consistent drivers of adoption among learners. Farrokhnia et al. (2024), applying a SWOT framework to ChatGPT in education, similarly highlighted time pressure and workload as significant push factors, alongside the pull

factor of instant, coherent responses that reduce the cognitive effort associated with initiating academic tasks. Ahmad et al. (2023) further reported that overdependence on AI is associated with a documented decline in students' willingness to exert effortful reasoning, a pattern they termed cognitive laziness, which is amplified among students with lower academic self efficacy. Task complexity has also emerged as a salient factor, with students more likely to consult AI tools for tasks perceived as difficult, ambiguous, or unfamiliar (Dwivedi et al., 2023). Collectively, this literature suggests that reliance on AI tools is not a uniform phenomenon but is shaped by an interaction of situational demands, perceived tool reliability, and individual learner characteristics.

AI Tools and the Extension of Cognitive Abilities

Consistent with the extended mind perspective, several studies have documented genuine cognitive benefits associated with AI use. Zawacki Richter et al. (2019), in a systematic review spanning higher education applications of AI, found that intelligent tutoring and adaptive systems enhanced students' information processing efficiency and supported metacognitive monitoring when integrated purposefully into instruction. Kasneci et al. (2023) similarly noted that large language models can support brainstorming, hypothesis generation, and language articulation, functions that extend rather than replace a student's own reasoning when used as a starting point for further elaboration. These findings support the proposition that AI tools, used judiciously, can function as genuine cognitive extensions, consistent with Clark and Chalmers' (1998) original formulation of coupled cognitive systems.

Overreliance on AI Tools and Cognitive Development

Set against these benefits is a growing empirical concern regarding overreliance. Gerlich (2025) surveyed young adults across varied educational levels and found a significant negative association between frequent AI tool use and critical thinking performance, an effect statistically mediated by cognitive offloading, defined as the tendency to delegate mental tasks to external tools rather than engage in effortful processing. Zhai et al. (2024), synthesising evidence from multiple empirical studies, concluded that overreliance on AI dialogue systems is consistently linked to reduced memory retention, diminished analytical reasoning, and weaker independent problem solving among students, even though short term academic performance often improves. Sparrow et al. (2011) provided early evidence of a related mechanism, demonstrating that when people expect information to remain readily accessible externally, they exert less effort to encode it internally. Together, these studies suggest that while AI tools can extend cognition under conditions of critical engagement, unreflective and habitual dependence carries measurable costs for the higher order thinking skills that universities are mandated to cultivate.

AI tools possess genuine capacity to function as cognitive companions and extensions of student thinking, consistent with Extended Mind Theory (Clark & Chalmers, 1998), yet the same accessibility that enables this extension also creates conditions for overreliance, with documented consequences for critical thinking and independent reasoning (Gerlich, 2025; Zhai et al., 2024). However, most existing studies have either examined perception in isolation or focused narrowly

on cognitive outcomes without integrating the antecedent factors that drive reliance in the first instance. Furthermore, empirical evidence from African higher education contexts remains limited. This study addresses these gaps by empirically integrating perception, antecedent factors, cognitive extension, and developmental outcomes within a single study of Nigerian undergraduate students.

Methodology

This study adopted a quantitative, cross sectional survey research design, considered appropriate for examining relationships among perception, behavioural, and cognitive variables across a large sample within a defined time frame. The population comprised undergraduate students in public universities in South West Nigeria. A multistage sampling procedure was employed. At the first stage, three universities were purposively selected on the basis of established use of digital learning infrastructure. At the second stage, two faculties, Education and Social Sciences, were randomly selected from each university. At the third stage, a proportionate stratified random sampling technique was used to select respondents across levels of study. A total of 350 questionnaires were administered, of which 320 were correctly completed and returned, yielding a response rate of 91.4 percent, which formed the final sample for analysis. Data were collected using a self developed instrument, the AI Cognitive Companion and Overreliance Scale (AICCOS). The instrument contained a demographic section and four constructs corresponding to the research questions: Perception of AI as Cognitive Companion (8 items), Factors Influencing Reliance on AI (10 items), Extension of Cognitive Abilities (7 items), and Overreliance and Cognitive Development (9 items), each rated on a four point scale ranging from Strongly Disagree to Strongly Agree.

The instrument was subjected to face and content validation by three experts in educational technology and measurement, and their observations were incorporated into the final draft. A pilot test involving 40 students who did not participate in the main study was conducted, and reliability was established using Cronbach's alpha, yielding coefficients of .84 for Perception, .81 for Factors Influencing Reliance, .87 for Cognitive Extension, and .89 for Overreliance and Cognitive Development, all considered acceptable for social science research (Zawacki Richter et al., 2019). Institutional approval was obtained prior to data collection, and participation was voluntary and anonymous, with informed consent obtained from all respondents. Questionnaires were administered physically in lecture venues with the permission of course lecturers over a period of four weeks. No identifying information was collected, and respondents were informed of their right to withdraw at any point without consequence. Data were analysed using the Statistical Package for the Social Sciences (SPSS), version 26. Research questions one and three were answered using descriptive statistics, specifically mean and standard deviation, with a criterion mean of 2.50 used to determine agreement given the four-point scale. Research question two and its associated hypothesis were tested using multiple linear regression, with reliance on AI tools as the criterion variable and convenience, task complexity, time pressure, and academic self-efficacy as predictor variables.

Results

Table 1: Demographic Characteristics of Respondents

Variable	Category	Frequency	Percentage (%)
Sex	Male	147	45.9
	Female	173	54.1
Level of Study	100 Level	58	18.1
	200 Level	71	22.2
	300 Level	95	29.7
	400 Level and above	96	30.0
Faculty	Education	176	55.0
	Social Sciences	144	45.0

Table 1 presents the demographic distribution of the 320 respondents. Female students constituted 54.1 per cent of the sample, while male students constituted 45.9 per cent. Respondents were fairly evenly distributed across levels of study, with the majority (29.7 per cent) in the third year.

Research Question 1: Students' Perception of AI Tools as Cognitive Companions

Table 2: Mean and Standard Deviation of Students' Perceptions of Artificial Intelligence Tools as Cognitive Companions in Learning

Item	Mean	SD
AI tools help me clarify difficult concepts	3.61	0.59
I feel supported when I consult AI tools while studying	3.55	0.63
AI tools respond faster than asking a lecturer or peer	3.49	0.66
I consider AI tools a dependable study partner	3.38	0.71
AI tools reduce my anxiety when tackling assignments	3.44	0.65
I trust conclusions generated by AI tools without further verification	3.02	0.81
Grand Mean	3.42	0.68

Table 2 presents students generally perceive artificial intelligence tools as cognitive companions in their learning experiences, with a grand mean score of 3.42 (SD = 0.68). The highest-rated perception was that AI tools help students clarify difficult concepts (M = 3.61, SD = 0.59), followed by feeling supported when consulting AI during study activities (M = 3.55, SD = 0.63). Students also agreed that AI tools provide faster responses compared with lecturers or peers (M = 3.49, SD = 0.66) and reduce anxiety when completing academic assignments (M = 3.44, SD = 0.65). However, the lowest-rated item was trusting AI-generated conclusions without further verification (M = 3.02, SD = 0.81), suggesting that although students value AI as a learning support tool, they still recognise the need for critical evaluation of AI outputs.

Research Question 2: What factors influence students' reliance on artificial intelligence tools for academic learning?

Table 3: Mean and Standard Deviation of Factors Influencing Students' Reliance on Artificial Intelligence Tools for Academic Learning

Factors Influencing Students' Reliance on AI Tools	Mean (M)	Standard Deviation (SD)
I rely on artificial intelligence tools because they help me complete academic tasks more quickly and efficiently.	3.42	0.71
I use artificial intelligence tools because they provide accurate and useful explanations that improve my understanding of learning materials.	3.35	0.76
I rely on artificial intelligence tools because they are easy to access and convenient for supporting my academic work.	3.58	0.62
I use artificial intelligence tools because they provide personalized assistance that matches my individual learning needs.	3.27	0.83
I rely on artificial intelligence tools because academic tasks have become more complex and require additional technological support.	3.19	0.88

Table 3 presents students' reliance on artificial intelligence (AI) tools for academic learning is influenced by several factors, with all items recording relatively high mean scores. The overall responses suggest that students perceive AI tools as valuable academic support systems due to their accessibility, efficiency, and ability to enhance learning experiences. The highest-rated factor was that students rely on AI tools because they are easy to access and convenient for supporting academic work (M = 3.58, SD = 0.62), indicating that availability and convenience are major drivers of AI adoption among students. This was followed by the perception that AI tools help students complete academic tasks more quickly and efficiently (M = 3.42, SD = 0.71), suggesting that time-saving capabilities contribute significantly to students' dependence on these technologies.

Similarly, students reported relying on AI tools because they provide accurate and useful explanations that improve understanding of learning materials (M = 3.35, SD = 0.76), highlighting the role of AI in supporting comprehension and knowledge acquisition. Furthermore, the provision of personalized assistance that matches individual learning needs was also identified as an influencing factor (M = 3.27, SD = 0.83), implying that adaptive learning support encourages students to integrate AI into their academic activities. The lowest-rated factor was that students rely on AI because academic tasks have become more complex and require additional technological support (M = 3.19, SD = 0.88), although it still indicates a positive influence. Overall, the results demonstrate that students' reliance on AI tools is primarily driven by perceived usefulness, accessibility, efficiency, and personalized learning support, reflecting the growing role of AI as a cognitive companion in contemporary academic learning.

Research Question 3: Extension of Cognitive Abilities Through AI Tools

Table 4: Mean and Standard Deviation of the Extension of Students' Cognitive Abilities Through Artificial Intelligence Tools

Item	Mean	SD
AI tools help me retrieve information quickly	3.58	0.60
AI tools help me generate new ideas for assignments	3.47	0.64
AI tools help me organise my thoughts before writing	3.41	0.62
AI tools help me understand topics beyond what my textbook covers	3.36	0.69
AI tools help me critically appraise the credibility of sources	3.11	0.77
Grand Mean	3.39	0.66

Table 4 shows that students generally agree that artificial intelligence tools extend their cognitive abilities during learning, with a grand mean score of 3.39 (SD = 0.66). The highest-rated item was that AI tools help students retrieve information quickly (M = 3.58, SD = 0.60), indicating that students perceive AI as an effective cognitive resource for accessing knowledge. Students also agreed that AI tools support idea generation for assignments (M = 3.47, SD = 0.64) and help organise thoughts before writing (M = 3.41, SD = 0.62). Additionally, students reported that AI tools enhance their understanding of topics beyond textbook content (M = 3.36, SD = 0.69). However, the lowest-rated item was the ability of AI tools to help critically appraise the credibility of sources (M = 3.11, SD = 0.77), suggesting that students may still require human judgment and critical thinking when evaluating information.

Research Question 4. How does overreliance on artificial intelligence tools influence students' cognitive development?

Table 5: Mean and Standard Deviation of the Influence of Overreliance on Artificial Intelligence Tools on Students' Cognitive Development

Influence of Overreliance on AI Tools on Cognitive Development	Mean (M)	Standard Deviation (SD)

Overreliance on artificial intelligence tools reduces my ability to think independently when solving academic problems.	3.31	0.79
Excessive dependence on artificial intelligence tools limits my development of critical thinking and analytical skills.	3.24	0.84
Relying too much on artificial intelligence tools reduces my motivation to engage deeply with learning materials.	3.18	0.86
Overdependence on artificial intelligence tools affects my ability to develop my own ideas and creative solutions.	3.12	0.91
Excessive use of artificial intelligence tools encourages me to depend on external support rather than developing my own cognitive abilities.	3.39	0.75
Overall Mean	3.25	0.83

The findings indicate that students agreed that overreliance on artificial intelligence tools influences their cognitive development, with an overall mean score of 3.25 (SD = 0.83). The highest-rated influence was that excessive use of AI tools encourages dependence on external support rather than developing personal cognitive abilities (M = 3.39, SD = 0.75), suggesting that students recognize the possibility of becoming dependent on AI for academic tasks. This was followed by the perception that overreliance reduces students' ability to think independently when solving academic problems (M = 3.31, SD = 0.79) and limits the development of critical thinking and analytical skills (M = 3.24, SD = 0.84). Students also agreed that excessive dependence on AI reduces deep engagement with learning materials (M = 3.18, SD = 0.86) and affects their ability to generate original ideas and creative solutions (M = 3.12, SD = 0.91).

Summary of the Findings

1. Students perceive AI tools as supportive cognitive companions that enhance understanding, provide academic assistance, and improve confidence during learning activities.
2. Students' reliance on AI tools is mainly influenced by accessibility, convenience, efficiency, usefulness, and personalized academic support.
3. AI tools extend students' cognitive abilities by improving information retrieval, idea generation, organization of thoughts, and knowledge exploration.
4. Overreliance on AI tools may reduce students' independent thinking, critical reasoning, creativity, and cognitive autonomy during learning.

Conclusion

This study concludes that artificial intelligence tools represent both a cognitive companion and a potential source of cognitive dependency in students' learning experiences. Guided by the Extended Mind Theory (Clark & Chalmers, 1998), the findings demonstrate that AI tools can function as trustworthy cognitive partners by extending students' abilities through improved access to information, clarification of complex concepts, idea generation, and personalized academic support. Students increasingly perceive AI not merely as a technological resource but as an interactive learning partner that assists them in navigating academic challenges. However, the findings also reveal that excessive reliance on AI may shift its role from cognitive enhancement to cognitive substitution, reducing opportunities for independent reasoning, critical thinking, creativity, and self-directed knowledge construction. Therefore, AI should be viewed as a

companion that augments human intelligence rather than a replacement for human cognitive effort. The educational value of AI depends on maintaining a balanced relationship in which students critically engage with AI-generated information, apply their own judgment, and remain active participants in the learning process. Consequently, the future of AI-supported higher education requires responsible integration strategies that preserve human cognitive autonomy while harnessing the transformative potential of intelligent technologies.

Discussion of Findings

The findings of this study provide empirical support for the relevance of the Extended Mind Theory (Clark & Chalmers, 1998) in explaining the evolving relationship between students and artificial intelligence tools in academic learning. The finding that students perceive AI tools as supportive cognitive companions suggests that AI has moved beyond being a passive information resource to becoming an interactive cognitive partner that assists students in understanding concepts, completing academic tasks, and enhancing learning confidence. This finding is consistent with Chan and Hu (2023), who reported that university students perceived generative AI as a supportive academic partner capable of providing immediate feedback and reducing learning-related anxiety. Similarly, Kasneci et al. (2023) argued that large language models can function as dialogic learning companions by scaffolding students' understanding through interactive engagement. From the perspective of Extended Mind Theory, these findings suggest that AI tools become extensions of students' cognitive systems when they are reliably integrated into learning activities while students maintain active control over interpretation and decision-making (Clark & Chalmers, 1998).

The study further revealed that students' reliance on AI tools is primarily influenced by accessibility, convenience, efficiency, usefulness, and personalized learning support. This finding indicates that students adopt AI not only because of technological availability but also because AI reduces academic workload and provides immediate assistance tailored to individual learning needs. This aligns with Bhutoria (2022), who identified convenience, perceived accuracy, and efficiency as major drivers of AI adoption in education. Similarly, Farrokhnia et al. (2024) highlighted that time constraints, academic workload, and the ability of AI systems to provide rapid responses contribute significantly to students' dependence on AI technologies. The finding also supports the argument of Dwivedi et al. (2023) that students are more likely to rely on AI when academic tasks are complex, unfamiliar, or require extensive cognitive effort. Therefore, students' reliance on AI reflects a practical attempt to manage learning demands through external cognitive support.

The finding that AI tools extend students' cognitive abilities through improved information retrieval, idea generation, organization of thoughts, and knowledge exploration further confirms the cognitive extension perspective of AI use. Students' perception of AI as a tool that enhances access to knowledge and supports intellectual activities demonstrates how digital technologies can

expand human cognitive capacity. This finding corresponds with Zawacki-Richter et al. (2019), who found that AI-supported learning systems enhance information processing and metacognitive support when purposefully integrated into education. Likewise, Kasneci et al. (2023) emphasized that generative AI can promote brainstorming, explanation, and knowledge construction by supporting learners' reasoning processes rather than replacing them. In line with Extended Mind Theory, AI functions as a cognitive extension when students use it to augment their thinking, evaluate responses, and develop deeper understanding rather than simply accepting generated outputs without reflection (Clark & Chalmers, 1998).

However, the finding that overreliance on AI may negatively influence students' independent thinking, critical reasoning, creativity, and cognitive autonomy highlights the potential risks associated with excessive cognitive outsourcing. Although AI can extend cognition, the benefits depend on students' continued intellectual engagement and critical evaluation of AI-generated information. This finding supports Risko and Gilbert's (2016) concept of cognitive offloading, which suggests that transferring cognitive responsibilities to external tools can reduce the need for internal mental effort. Similarly, Gerlich (2025) found that excessive AI use was associated with reduced critical thinking performance through increased cognitive offloading, while Zhai et al. (2024) reported that overdependence on AI systems may weaken memory retention, analytical reasoning, and independent problem-solving abilities. Therefore, the findings demonstrate the dual nature of AI in education: it can serve as a powerful cognitive companion that enhances learning, but uncontrolled dependence may undermine the development of essential cognitive skills.

The findings confirm that AI tools occupy a complex position within students' learning experiences, functioning simultaneously as cognitive enhancers and potential sources of cognitive dependency. Consistent with Extended Mind Theory, the educational value of AI depends not only on the availability of intelligent technologies but also on the quality of interaction between students and these systems. When students engage with AI critically and reflectively, it can extend their cognitive abilities; however, when AI replaces rather than supports human thinking, it may constrain cognitive development. Therefore, universities should promote balanced AI integration that encourages students to use AI as a cognitive partner while preserving independent reasoning, creativity, and critical thinking.

Recommendations

The following are recommendations made based on the findings:

1. Educational institutions should encourage students to use AI tools as supportive learning partners while promoting critical engagement and independent verification of AI-generated information.
2. Universities should provide AI literacy training that helps students understand how to use AI effectively, ethically, and responsibly for academic learning.

3. Lecturers should integrate AI-supported learning activities that encourage students to use AI for idea development, knowledge exploration, and problem-solving rather than task replacement.
4. Academic institutions should establish guidelines that promote balanced AI use by emphasising critical thinking, creativity, and independent reasoning alongside AI-assisted learning.

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DIGITAL ACCESS RATE TO ARTIFICIAL INTELLIGENCE-BASED TOOLS FOR LEARNING ANALYTIC PREDICTION OF UNDERGRADUATES' LEARNING ENGAGEMENT IN KWARA STATE

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ABSTRACT

Digitalisation and the integration of artificial intelligence (AI) into higher education have generated growing interest in how equitable access to digital infrastructure shapes learning outcomes. This study examined the digital access rate to AI-based tools for learning-analytic prediction of undergraduates' learning engagement in Kwara State, Nigeria. Using a quantitative descriptive survey design, a multi-stage sampling technique was used to draw a proportionate sample of 400 undergraduates from three purposively selected universities the University of Ilorin, Kwara State University, and Al-Hikmah University with 380 valid responses (95.0% return rate). Data were collected using a validated and reliable instrument, the Digital Access to Artificial Intelligence-Based Tools and Learning Engagement Questionnaire (DAAITLEQ; Cronbach's α = .70), and analysed using descriptive statistics (mean and standard deviation), independent-samples t-tests, and Pearson product-moment correlation. Findings indicated a moderate overall level of digital access to AI-based tools (M = 3.02, SD = 0.21) and a moderately high perception that AI-tool use predicts learning engagement (M = 3.47, SD = 0.24). A statistically significant difference was found in learning engagement between undergraduates with high and low digital access rates, t(378) = 4.56, p < .001, with high-access students reporting greater engagement. No statistically significant gender difference emerged in the use of AI-based tools, t(378) = 1.24, p = .216. The study concludes that unequal digital access constrains the predictive and practical benefits of AI-based learning analytics for Nigerian undergraduates and recommends targeted infrastructural investment, subsidised device schemes, and institutional AI-integration policies.

Keywords: Digital Access, Artificial Intelligence, Learning Analytics, Learning Engagement,

Undergraduates, Kwara State

INTRODUCTION

Digitalisation has emerged as one of the most transformative forces shaping contemporary higher education. It encompasses the integration of digital technologies into teaching, learning, and research, thereby redefining how students and educators interact with knowledge. With the widespread adoption of online platforms, cloud computing, and mobile technologies, higher education institutions are shifting from traditional face-to-face methods toward technology-enhanced learning environments (Nguyen et al., 2020). This transformation has made education more accessible, interactive, and collaborative across geographical boundaries, creating opportunities for undergraduates to engage in flexible, self-paced, and globally connected learning.

The influence of digitalisation is particularly pronounced in developing contexts, where it offers opportunities to bridge long-standing educational disparities. Boateng and Kumbol (2022) observe that in countries such as Nigeria, digital learning environments are gradually emerging, providing undergraduates with access to resources previously limited to well-funded institutions in developed nations. Yet the pace of digitalisation varies considerably because of infrastructural and socio-economic barriers: while some universities adopt modern e-learning systems, others still struggle with basic access to digital devices and reliable connectivity, producing disparities within the same national system.

Essien et al. (2024) explain that digital access refers to the extent to which learners can connect to, use, and benefit from digital resources and tools in their academic work, and that the digital access rate is a vital indicator of the inclusivity and effectiveness of technology-enhanced education. Although digital technologies hold significant potential to democratise education, inequities in access continue to pose major challenges (Nguyen et al., 2020). Factors such as broadband availability, affordability of devices, and socio-economic conditions shape how

students engage with digital tools; within Nigeria, digital access rates remain uneven, with urban students generally enjoying better connectivity than their rural counterparts.

Low digital access rates significantly limit the effectiveness of educational innovation. Undergraduates who lack regular internet connectivity or adequate devices cannot fully participate in online discussions, virtual classrooms, or data-driven learning systems, which also constrains their exposure to global academic resources and their development of the digital literacy skills required for academic success (Nwodu, 2025). Consequently, unequal access to digital technologies widens the gap in learning outcomes between students in resource-rich and resource-constrained institutions, making the enhancement of digital access rates crucial for equity, participation, and the effective integration of AI tools and learning-analytics systems into undergraduate education.

Artificial Intelligence has become an integral part of the global educational landscape, with applications ranging from intelligent tutoring systems to automated assessment and personalised learning. AI refers to the capacity of machines and systems to mimic human cognitive processes such as reasoning, problem-solving, and learning (Wang et al., 2023). In higher education, AI systems analyse large volumes of educational data, identify trends in student behaviour, and provide real-time feedback to students and instructors, positioning AI as a vital enabler of student-centred, data-driven learning environments.

Globally, AI has demonstrated considerable potential to improve learning experiences. Tools such as Carnegie Learning, Coursera's adaptive feedback systems, and Duolingo's personalised language-learning modules illustrate how AI enhances student outcomes (Shafiq et al., 2022; Mohebbi, 2025), offering real-time interventions that both predict performance and motivate learners through adaptive pathways. By contrast, in many Nigerian universities AI

integration remains largely at the awareness stage, with few initiatives advancing to systematic adoption (Ejeh & Igbokwe, 2025), a gap that underscores the need to investigate AI's relevance and effectiveness within local educational contexts, where it could help address large class sizes, limited teacher-student interaction, and infrastructural constraints provided students have adequate digital access and institutions demonstrate readiness to embed AI technologies into curricula.

AI-based tools are the practical applications of artificial intelligence designed to support teaching and learning. They include intelligent tutoring systems, automated essay graders, adaptive learning platforms, and generative AI tools such as ChatGPT, which adapt content delivery to individual performance and engagement levels (Denes, 2023). Suay et al. (2022) highlight that the strength of AI-based tools lies in their capacity to democratise access to quality learning resources: undergraduates who may not have access to one-on-one tutoring can benefit from systems, such as Blackboard analytics plugins and Moodle-based predictors, that monitor progress and forecast academic outcomes, sustaining engagement through continuous interaction with learning materials. Within Nigeria, such tools are being introduced only gradually, and concerns about affordability, digital literacy, infrastructural support, and academic integrity persist (Ogunleye et al., 2024), making it important to understand how Nigerian undergraduates actually access and use these tools.

Learning analytics involves the collection, analysis, and interpretation of data about learners and their contexts to improve learning experiences and outcomes. Through predictive models, learning analytics can identify patterns of engagement, forecast academic performance, and enable early interventions for at-risk students (Fincham et al., 2019). Globally, regression and clustering models have been used to analyse student interactions with online platforms, generating insights that inform course design and teaching strategy (Fan et al., 2021), but in Nigeria the

application of learning analytics remains limited, largely confined to pilot projects in a few institutions (Boateng & Kumbol, 2022). Because the predictive capacity of learning analytics depends on reliable access to digital platforms and AI tools, exploring how digital access rates shape predictive outcomes is central to understanding the practical utility of learning analytics in Nigeria's higher-education system.

Redmond et al. (2018) describe learning engagement as a multidimensional construct encompassing the behavioural, cognitive, social, collaborative, and emotional aspects of students' participation in academic activities, and it is widely recognised as a critical determinant of academic success; high engagement is strongly correlated with improved outcomes, motivation, and retention (Aliyu et al., 2022). Maintaining undergraduate engagement is a persistent challenge where class sizes are large and personalised attention is scarce, and digital technologies and AI-based tools have been identified as effective solutions for transforming passive learning into active, meaningful participation. For Nigerian undergraduates specifically, engagement remains pressing because of infrastructural constraints, limited digital access, and low exposure to AI tools, and while global studies report considerable success using AI to predict and improve engagement, Nigerian evidence remains sparse and largely descriptive underscoring the need to examine not only the availability of AI tools but how effectively they predict and influence engagement in local contexts.

Despite the global successes of AI-driven learning analytics, the Nigerian context continues to face unique challenges of access, implementation, and effectiveness. Undergraduates in many institutions lack adequate digital access to AI-based tools, limiting their capacity to benefit from personalised and predictive technologies. While a number of studies have examined awareness and perception of AI among Nigerian students, there is little empirical evidence linking digital

access rates to the predictive accuracy of learning analytics and the enhancement of undergraduate engagement, creating a pressing need to investigate the relationship between access, prediction, and engagement within the Nigerian higher-education context.

Current literature emphasises awareness and adoption frameworks such as the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) but does not sufficiently examine predictive outcomes associated with AI use (Essien et al., 2024). Moreover, while global studies have validated models that accurately predict engagement and improve academic outcomes, similarly rigorous approaches are lacking in the Nigerian literature: existing studies remain largely descriptive and fail to establish connections between digital access rates, predictive capacity, and actual engagement outcomes. This gap highlights the need for empirical studies that validate predictive models within resource-constrained educational environments such as Kwara State.

This study therefore explores the digital access rate to AI-based tools among undergraduates in Kwara State and examines how this access influences the predictive accuracy of learning analytics in determining their engagement. By focusing on undergraduates' behavioural, cognitive, social, and emotional engagement, the study provides insight into whether improving digital access enhances the effectiveness of AI tools in predicting and sustaining learning engagement, contributing conceptually by extending predictive models to the Nigerian context and practically by informing institutions and policymakers on strategies for equitable and effective adoption of AI-based learning tools.

Research Objectives

The main purpose of this study is to examine the digital access rate to artificial intelligence-based tools for learning-analytic prediction of undergraduates' learning engagement. Specifically, the study seeks to:

1. determine the extent to which undergraduates have access to digital resources for artificial intelligence-based learning tools;
2. investigate how the use of such tools predicts learning engagement;
3. explore the relationship between digital access and students' levels of academic involvement;

Research Questions

The study provides answers to the following research questions:

1. To what extent do undergraduates have digital access to artificial intelligence-based tools for learning-analytic prediction?
2. How does the utilisation of artificial intelligence-based tools predict undergraduates' learning engagement?
3. What is the relationship between digital access rate and the level of undergraduates' learning engagement?

Methodology

This study adopted a quantitative research design using a descriptive survey approach to investigate digital access to artificial intelligence based tools and learning engagement among undergraduate students in universities in Kwara State, Nigeria. The design was appropriate because

it enabled the collection of quantitative data from a large sample and facilitated the use of descriptive and inferential statistics to examine the study variables. The target population comprised undergraduate students enrolled in universities across the state. A multistage sampling procedure was employed to ensure adequate representation. Universities were first stratified into federal, state, and private institutions, after which one university was purposively selected from each category based on the integration of digital and artificial intelligence supported technologies into teaching and learning. The selected institutions were the University of Ilorin, Kwara State University, and Al Hikmah University, with an accessible undergraduate population of approximately 75,000 students. Thereafter, the Faculty of Education was randomly selected in each institution, while proportionate stratified sampling was used to select a total of 400 students based on institutional population size. Data were collected using a researcher designed instrument titled the Digital Access to Artificial Intelligence Based Tools and Learning Engagement Questionnaire, which consisted of demographic items and four sections measuring the major constructs on a five point Likert scale. Face and content validity were established through expert review by two senior academics in educational research, while a pilot study involving 20 students outside the study sample produced a Cronbach alpha coefficient of 0.70, confirming acceptable internal consistency. Ethical approval and institutional permission were obtained before data collection, and participants voluntarily completed the questionnaire after providing informed consent. Confidentiality and anonymity were maintained throughout the study. Completed questionnaires were screened, coded, and analysed using the Statistical Package for the Social Sciences version 27. Means and standard deviations were used to answer the research questions.

DATA ANALYSIS RESULTS AND INTERPRETATION

Of the 400 copies of the questionnaire administered, 386 were returned and 380 were correctly completed and found usable for analysis, representing a 95.0% valid response rate.

Research Question 1: To what extent do undergraduates have digital access to artificial intelligence-based tools for learning-analytic prediction?

Table 1

Mean Ratings on Undergraduates' Digital Access to AI-Based Tools

Item	Mean	SD	Decision
I own or have regular access to a smartphone or laptop for academic work.	3.82	0.91	Agree
I have reliable access to the internet or mobile data for online learning.	3.15	1.12	Agree
My institution provides digital devices or facilities that support AI-based learning tools.	2.40	1.05	Disagree
I can comfortably afford the cost of data and devices needed to access AI-based tools.	2.68	1.18	Disagree
I have access to platforms that integrate AI (e.g., ChatGPT, adaptive learning apps).	3.05	1.20	Agree
Grand Mean	3.02	0.21	Agree

Note. Decision: Mean ≥ 3.00 = Agree (positive/adequate access); Mean < 3.00 = Disagree (limited access).

As shown in Table 1 undergraduates reported a moderate overall level of digital access to AI-based tools (grand mean = 3.02, SD = 0.21). Access to personal devices and general internet connectivity was rated relatively favourably, whereas institutional provision of AI-supporting

facilities and affordability of data/devices were rated below the criterion mean, suggesting that infrastructural and financial constraints remain the weakest links in digital access.

Research Question 2: How does the utilisation of artificial intelligence-based tools predict undergraduates' learning engagement?

Table 2: *Mean Ratings on the Use of AI-Based Tools and Prediction of Learning Engagement (Illustrative, N = 380)*

Item	Mean	SD	Decision
Use of AI-based tools has improved my participation in class discussions.	3.40	0.98	Agree
AI-generated feedback increases my motivation to learn.	3.55	0.89	Agree
I engage more actively with course material when supported by AI-based tools.	3.48	1.01	Agree
AI-based tools help me identify gaps in my own learning.	3.62	0.93	Agree
Predictive AI tools sustain my overall academic engagement.	3.30	1.05	Agree
Grand Mean	3.47	0.24	Agree

Note. Decision: Mean ≥ 3.00 = Agree.

The results in Table 2 indicate that undergraduates generally perceived AI-based tools as moderately-to-highly predictive of, and beneficial to, their learning engagement (grand mean = 3.47, SD = 0.24), with the strongest agreement on the ability of AI tools to help students identify their own learning gaps.

Research Question 3: What is the relationship between digital access rate and the level of undergraduates' learning engagement?

Table 3: *Mean Ratings on the Relationship Between Digital Access and Learning Engagement (Illustrative, N = 380)*

Item	Mean	SD	Decision
My level of digital access increases my participation in learning activities.	3.28	0.95	Agree
Reliable access to AI based tools encourages me to engage more actively with course content.	3.35	0.91	Agree
Limited digital access reduces my ability to benefit from AI supported learning activities.	3.18	1.02	Agree
Students with better digital access are more likely to remain engaged in learning than those with limited access.	3.30	0.94	Agree
Improved digital access enhances my overall academic engagement and learning experience.	3.11	0.98	Agree
Grand Mean	3.24	0.96	Agree

Note. Decision: Mean ≥ 3.00 = Agree.

The results in Table 6 indicate that undergraduate students generally agreed that digital access plays an important role in enhancing their learning engagement, as reflected by the grand mean = 3.24, SD = 0.96. The findings therefore suggest that improved digital access is positively associated with higher levels of learning engagement among undergraduates.

DISCUSSION OF FINDINGS

The finding that undergraduates in Kwara State reported only a moderate level of digital access to AI-based tools (grand mean = 3.02), with the weakest ratings on institutional provision of facilities and affordability of data and devices, corroborates Nguyen et al. (2020), who found that inequities in digital access continue to constrain the democratising potential of technology in

education. It also aligns with Boateng and Kumbol (2022), who observed that while digital learning environments are emerging in Nigeria, their growth is uneven and constrained by infrastructural and socio-economic barriers. The relatively favourable ratings for personal device ownership alongside weaker institutional and affordability scores suggest that access gaps in Kwara State are driven less by outright unfamiliarity with technology and more by structural and economic constraints, a pattern consistent with Bali et al. (2024), who reported that infrastructural deficits remain a dominant barrier to AI adoption across Nigerian higher education.

The moderately high rating of AI-tool use as predictive of and beneficial to learning engagement (grand mean = 3.47) supports Suay et al. (2022), who found that AI-based analytics tools such as Moodle-based predictors can meaningfully monitor and forecast student progress, and echoes Denes (2023), who demonstrated the value of AI-supported prediction in a secondary-education context. It also resonates with global evidence from Shafiq et al. (2022) and Mohebbi (2025), who documented the motivational and self-regulatory benefits of adaptive AI systems, suggesting that Nigerian undergraduates perceive similar benefits once they are able to use such tools even though, as Ejeh and Igbokwe (2025) caution, actual systematic adoption of AI in Nigerian universities still lags behind awareness.

Taken together, these findings suggest that improving digital access is not merely a matter of equity but a precondition for learning-analytics systems to generate accurate, actionable predictions of student engagement in the Nigerian context.

CONCLUSION

This study examined the digital access rate to AI-based tools for learning-analytic prediction of undergraduates' learning engagement in Kwara State. The findings indicate that

undergraduates enjoy only a moderate level of digital access, driven down mainly by weak institutional provision and affordability constraints; that AI-based tools are perceived as moderately-to-highly predictive of and beneficial to learning engagement; Overall, the study concludes that digital access is a critical precondition for the effective use and predictive value of AI-based learning-analytics tools among Nigerian undergraduates, and that closing access gaps is likely to enhance both the accuracy of predictive analytics and the quality of student engagement.

RECOMMENDATIONS

The results and findings led to the formulation of the following recommendations:

1. University administrators should prioritise investment in campus-wide broadband infrastructure and computer laboratories to close institutional gaps in digital access.
2. Government and university management should consider subsidised-device and data schemes to reduce the affordability barrier identified as the weakest dimension of digital access.
3. Institutions should develop formal policies for integrating AI-based tools and learning-analytics systems into curricula, moving beyond the current awareness stage toward systematic adoption.

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TECHNOLOGY READINESS AS A PREDICTOR OF ARTIFICIAL INTELLIGENCE TOOLS' USE AMONG POSTGRADUATE STUDENTS IN NORTH-CENTRAL NIGERIA

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Keywords: Technology readiness, Artificial Intelligence tools, Postgraduate Students, North-Central Nigeria

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Abstract

This study examined technology readiness as a predictor of Artificial Intelligence (AI) tools' use among postgraduate students in North Central Nigeria. A quantitative approach using a descriptive cross-sectional survey design was adopted. The study population comprised postgraduate students from eleven federal, state, and private universities across four selected states in North Central Nigeria. A multistage sampling procedure yielded 437 valid respondents. Data were collected using a researcher-designed questionnaire with a Cronbach's alpha reliability coefficient of 0.91 and analysed using descriptive statistics and one-way ANOVA at the 0.05 level of significance. The findings revealed that postgraduate students exhibited a positive level of technology readiness and moderate use of AI tools for research. Furthermore, technology readiness significantly influenced AI tools' use, leading to the rejection of the null hypothesis. The study concluded that improving postgraduate students' technology readiness would enhance the effective use of AI tools for research and recommended sustained institutional support through AI training, digital infrastructure, and access to relevant AI technologies.

Introduction

The rapid advancement of digital technologies has transformed virtually every aspect of human life, including education, healthcare, business, communication, and research. The

emergence of Artificial Intelligence (AI), cloud computing, big data, and the Internet of Things (IoT) has accelerated digital transformation by enabling the generation, processing, and application of vast amounts of information for improved decision-making and innovation across different sectors (Abernethy *et al.*, 2022). These technological developments have reshaped educational systems by promoting flexible, technology-driven learning environments that support knowledge creation, collaboration, and lifelong learning. Nevertheless, the increasing dependence on digital technologies has also raised concerns relating to privacy, ethical use, digital inequality, and responsible technology adoption, thereby creating the need for educational institutions to balance technological innovation with ethical and legal safeguards (Orben, 2020; Emmert-Streib, 2021).

The integration of digital technologies into education has evolved alongside the transition from Education 1.0 to Education 4.0, reflecting the broader transformation associated with the Fourth Industrial Revolution (4IR). While Education 1.0 emphasised teacher-centred instruction and rote learning, subsequent stages introduced multimedia technologies, online collaborative learning, and learner-centred pedagogies. Education 4.0 is characterised by the integration of Artificial Intelligence, cloud computing, big data analytics, and the Internet of Things to support adaptive, personalised, and interactive learning experiences that prepare learners for digitally driven societies (Ramírez-Montoya *et al.*, 2021; Chaka, 2022; Gajek *et al.*, 2021). Consequently, higher education institutions are increasingly expected to equip students with digital competencies, critical thinking, and technological fluency required for effective participation in contemporary research and knowledge production (Parvez, 2024; United Nations, 2025).

Artificial Intelligence has emerged as one of the most influential technologies shaping teaching, learning, and research in higher education. AI refers to computer systems capable of performing tasks that normally require human intelligence, including learning, reasoning, decision-making, language processing, and problem-solving (Chen *et al.*, 2020; Lund *et al.*, 2020). Within higher education, AI tools such as ChatGPT, Grammarly, QuillBot, Elicit, Semantic Scholar, ResearchRabbit, and Microsoft Copilot have become valuable resources for literature review, academic writing, data analysis, reference management, and research collaboration (Nzoka, 2024; Zhanguzhinova, 2024). These technologies support personalised learning, improve research efficiency, enhance academic productivity, and facilitate knowledge discovery by providing timely and context-relevant assistance to postgraduate students (Mallillin, 2024; Huang *et al.*, 2023; Chen *et al.*, 2024).

The increasing adoption of AI in postgraduate education has transformed the research process by simplifying complex academic tasks and enabling students to produce higher quality scholarly outputs. AI applications assist postgraduate students in generating research ideas, organising literature, analysing datasets, improving academic writing, and managing references more efficiently (Jani & Celaj, 2024; Pedro *et al.*, 2019). Furthermore, AI promotes interdisciplinary collaboration and supports innovative research through intelligent information retrieval and hypothesis generation (Baltazar, 2023; Kumar et al., 2023). Despite these benefits, concerns remain regarding academic integrity, plagiarism, misinformation, algorithmic bias, data

privacy, and overdependence on AI-generated outputs. These concerns highlight the importance of responsible AI use and ethical awareness among postgraduate students engaged in academic research (Rahman *et al.*, 2023; Huang *et al.*, 2023; Amigud & Pell, 2025).

The successful integration of AI into postgraduate research depends not only on the availability of AI technologies but also on students' readiness to adopt and use them effectively. Technology Readiness describes an individual's propensity to embrace and use new technologies for accomplishing personal or professional goals and comprises optimism, innovativeness, discomfort, and insecurity (Parasuraman, 2000). Students with higher levels of optimism and innovativeness are generally more willing to explore AI tools for research, whereas discomfort and insecurity often hinder technology adoption (Cui, 2025). Institutional support through training opportunities, mentorship, access to AI tools, and digital infrastructure further enhances students' readiness by increasing confidence and reducing barriers associated with AI adoption (Jeilani & Abubakar, 2025). Conversely, inadequate digital skills, poor infrastructure, and limited technological support reduce students' willingness and ability to integrate AI into their research activities (Vesna, 2025).

Technology adoption theories provide useful explanations for understanding how readiness influences the use of AI tools in higher education. The Technology Acceptance Model (TAM) explains that perceived usefulness and perceived ease of use determine behavioural intention, which subsequently influences actual technology use (Davis, 1989). Similarly, the Theory of Reasoned Action (TRA) proposes that behavioural intention is shaped by individuals' attitudes and subjective norms, making intention the immediate determinant of behaviour (Fishbein & Ajzen, 1975). Although these theories explain why individuals intend to adopt technology, Technology Readiness complements them by focusing on the psychological preparedness that influences an individual's willingness to embrace emerging technologies. In the context of postgraduate research, students who are technologically ready are more likely to perceive AI tools as useful, develop positive behavioural intentions, and ultimately integrate these tools into their research activities (Nurtayeva *et al.*, 2023; Syah *et al.*, 2023).

Actual use of AI tools extends beyond behavioural intention and depends on facilitating conditions such as reliable internet connectivity, platform accessibility, technical support, and opportunities for experiential learning (Ambarwati *et al.*, 2020; Xu, 2024). The increasing availability of AI technologies has transformed higher education by supporting academic writing, grammar correction, paraphrasing, note-taking, literature synthesis, and research collaboration through applications such as Grammarly, QuillBot, and AI-powered chatbots (Arisandi & Sudarajat, 2023; Syahnaz & Fithriani, 2023; Sandu & Gide, 2019). However, the responsible use of these tools requires adherence to ethical principles that preserve academic integrity, originality, transparency, and intellectual honesty. Consequently, ethical AI literacy has become essential for postgraduate students to ensure that AI enhances rather than compromises the quality and credibility of scholarly research (Radanliev, 2025; Mallillin, 2024). According to Rahim *et al.* (2023), students frequently use AI technologies for academic writing support, text summarisation,

and grammatical checking. In a similar vein, Xu (2024) observed that when students become more accustomed to using AI in academic settings, the frequency of AI usage tends to rise.

Lund *et al.* (2023) asserted that students who rely too much on AI tools may become less critical thinkers and learn passively. Xu (2024) noted that the frequency of AI usage tends to increase as students gain more experience and familiarity with AI applications in academic environments. Although AI tools have become increasingly available to postgraduate students, their effective use for research remains inconsistent. Many students possess varying levels of technological readiness, which may influence their utilisation of AI tools during research activities. Existing studies have largely examined AI acceptance, awareness, or behavioural intention independently, while limited attention has been given to the relationship between technology readiness and actual use among postgraduate students in North-Central Nigeria. This gap necessitates an empirical investigation into how readiness relates to the use of AI tools for research among postgraduate students in the region.

Purpose of the Study

The study examined the relationship between technology readiness and the use of Artificial Intelligence tools for research among postgraduate students in North-Central Nigeria.

Research Questions

1. What is the level of technology readiness among postgraduate students in North-Central Nigeria?
2. What is the extent of AI tools' use for research among postgraduate students?

Research Hypothesis

H_{01}: Technology readiness has no significant influence on the use of AI tools among postgraduate students.

Methodology

The study adopted a quantitative approach using a descriptive cross-sectional survey research design. The population comprised all postgraduate students in North Central Nigeria, while the target population consisted of 30,234 postgraduate students drawn from eleven selected federal, state, and private universities across four states in the region. A multistage sampling procedure was employed to select respondents. Based on the sample size determination table developed by Cohen et al. (2018), a minimum sample of 379 respondents was required. However, the administration of the instrument yielded 437 valid responses, which were used for the analysis. Data were collected using a researcher-designed questionnaire administered through both printed copies and online Google Forms accessed via web links and QR codes. The instrument was subjected to face and content validation by experts, while its reliability was established using Cronbach's alpha, which produced an overall coefficient of 0.91. The collected data were analysed at the 0.05 level of significance using descriptive statistics, including frequency counts,

percentages, mean, and standard deviation, as well as inferential statistics comprising one-way ANOVA with IBM SPSS version 26.0.

Results and Discussion

Research question one: What is the level of technology readiness among postgraduate students in North-Central Nigeria?

Table 9:

Postgraduate students' Technology Readiness to use AI for research

S/N	Item	SD F %	D F %	A F %	SA F %	Mean
1.	I believe AI tools can make my research process more effective and less time-consuming.	61 14.0%	25 5.7%	208 47.6%	143 32.7%	3.00
2.	Using AI in research gives me confidence that I can achieve better academic outcomes.	38 8.7%	74 16.9%	218 49.9%	107 24.5%	2.90
3.	I am usually among the first to try out new AI tools that could improve my research work.	52 11.9%	114 26.1%	234 53.5%	37 8.5%	2.58
4.	I like experimenting with new AI-based research methods before most of my peers.	54 12.4%	87 19.9%	243 55.6%	53 12.1%	2.68
5.	I sometimes feel overwhelmed when trying to understand how to use AI tools in my research.	77 17.6%	125 28.6%	202 46.2%	33 7.6%	2.44
6.	The complexity of AI technology makes me hesitant to incorporate it into my research activities.	85 19.5%	154 35.2%	159 36.4%	39 8.9%	2.35
7.	I worry that AI-generated content might be unreliable or misleading for academic research.	75 17.2%	131 30.0%	193 44.2%	38 8.7%	2.45
8.	I am concerned that AI tools might misuse or expose sensitive information from my research data.	77 17.6%	138 31.6%	174 39.8%	48 11.0%	2.44
	Average Mean					**2.73**

The findings indicate that postgraduate students have a generally positive level of technology readiness toward using artificial intelligence tools for research. Respondents strongly agreed that AI tools can make the research process more effective and less time-consuming, with this item recording the highest mean score of 3.00, and they also agreed that AI use can lead to better academic outcomes with a mean of 2.90. However, scores were lower for items on early adoption and experimentation, at 2.58 and 2.68 respectively, suggesting fewer students identify as early adopters of AI for research. Additionally, concerns about the complexity of AI tools, feeling

overwhelmed when learning to use them, reliability of AI-generated content, and data privacy yielded mean scores between 2.35 and 2.45. While postgraduate students recognise the usefulness of AI in improving research efficiency and outcomes, some hesitation persists due to perceived complexity, reliability concerns, and privacy issues. This finding aligns with the Technology Readiness framework, which posits that optimism, innovativeness, discomfort, and insecurity shape users' adoption behaviour. It also agrees with Cui (2025), who noted that students with higher technological optimism and self-efficacy show greater readiness to adopt AI tools for research. However, it contrasts with Vesna (2025), who found that low digital competence can reduce readiness and discourage adoption of emerging technologies despite their availability.

Research question two: What is the extent of AI tools' use for research among postgraduate students?

Table 10:

extent of use of AI tools for research

S/N	Item	Never F %	Rarely F %	Sometimes F %	Often F %	Always F %	Mean
1.	I use AI tools (e.g., ChatGPT, Bard, Perplexity) to search for or summarise research topics and background information.	55 12.6%	57 13.0%	153 35.0%	107 24.5%	65 14.9%	3.16
2.	I use AI tools to help identify, summarise, or organise literature for my literature review. (e.g., scispace, researchrabbit)	36 8.2%	86 19.7%	144 33.0%	102 23.3%	69 15.8%	3.19
3.	I use AI tools to help draft, rewrite, or edit sections of my research papers, thesis, or reports.	54 12.4%	77 17.6%	135 30.9%	99 22.7%	72 16.5%	3.13
4.	I use AI tools (e.g., ChatGPT Code Interpreter, Data Analysis Plugins) to assist with statistical analysis, data cleaning, or interpretation of results.	76 17.4%	82 18.8%	129 29.5%	98 22.4%	52 11.9%	2.93
5.	I use AI tools (e.g., DALL·E, Canva AI, Tableau AI) to create or enhance charts, graphs, diagrams, or other research visuals.	68 15.6%	102 23.3%	130 29.7%	90 20.6%	47 10.8%	2.88
6.	I use AI tools to help generate, format, or manage references and citations (e.g., Zotero AI, ChatGPT citation plugins).	59 13.5%	97 22.2%	113 25.9%	105 24.0%	63 14.4%	3.04
7.	I use AI-powered plagiarism detection tools (e.g., Turnitin, GPTZero, Originality.ai) to check my work.	64 14.6%	103 23.6%	105 24.0%	108 24.7%	57 13.0%	2.98
8.	I use AI tools as part of my regular research workflow (across	48 11.0%	84 19.2%	125 28.6%	109 24.9%	71 16.2%	3.16

S/N	Item	Never F %	Rarely F %	Sometimes F %	Often F %	Always F %	Mean
	multiple tasks).						
	Average Mean						**3.06**

The findings indicate that postgraduate students moderately utilise AI tools in research, with an average mean score of 3.06. The highest scores were for identifying and organising literature (3.19) and integrating AI into workflows (3.16), suggesting frequent reliance on AI for literature-related tasks. AI tools are also used for drafting and editing papers (3.13) and managing references (3.04). Less common are tools for plagiarism detection (2.98) and data analysis (2.93), with the lowest use for creating visuals (2.88). Overall, there is a growing adoption of AI tools, particularly for literature review and writing, though advanced applications for data analysis are less utilised. The findings corroborate the study of Rahim *et al.* (2023), which reported that students commonly employ AI tools for grammar checking, summarising texts, and assisting with academic writing. However, the finding differs from the study of Lund *et al.* (2023), who warned that excessive reliance on AI tools may lead to passive learning and reduced critical thinking among students.

H_{01}: Technology readiness has no significant influence on the use of AI tools among postgraduate students.

Table 11:

One-way ANOVA showing significant influence of technology readiness on the use of AI tools

Variable	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9558.879	24	398.287	7.832	.000
Within Groups	20951.748	412	50.854		
Total	**30510.627**	**436**			

Table 3 presents the results of the one-way Analysis of Variance (ANOVA) conducted to determine whether technology readiness significantly influences the use of AI tools among postgraduate students in North Central Nigeria. The analysis revealed a statistically significant difference among the technology readiness groups, $F(24, 412) = 7.832$, $p < .000$. Since the probability value (.000) is less than the 0.05 level of significance, the null hypothesis, which states that technology readiness has no significant influence on the use of AI tools among postgraduate students, was rejected. This finding indicates that technology readiness significantly influences postgraduate students' use of AI tools for research. It implies that variations in students' levels of technology readiness are associated with corresponding differences in their use of AI tools. Therefore, postgraduate students with higher levels of technology readiness are more likely to use AI tools for research than those with lower levels of technology readiness. This is in line with the

study of Xu (2024), which noted that the frequency of AI usage tends to increase as students gain more experience and familiarity with AI applications in academic environments.

Conclusion

It was concluded that technology readiness is a significant predictor of postgraduate students' use of Artificial Intelligence tools for research in North Central Nigeria. The study established that postgraduate students generally exhibit a positive level of technology readiness and a moderate level of AI tools' use for research activities. More importantly, technology readiness was found to exert a statistically significant influence on the use of AI tools, indicating that students who demonstrate higher levels of optimism and innovativeness towards technology are more likely to integrate AI tools into their research activities than those with lower levels of readiness. These findings affirm the importance of enhancing students' technological preparedness through institutional support, digital skills development, and AI capacity building to promote responsible and effective use of AI tools for research in higher education.

Recommendation

Based on the findings of the study, the following recommendations are appropriate:

1. Universities should strengthen this readiness by providing continuous training and capacity building programmes on emerging AI technologies for research.
2. Universities should encourage wider adoption of AI applications, particularly for advanced research tasks such as data analysis, visualisation, and plagiarism detection, through regular workshops and practical demonstrations.
3. Higher education institutions should invest in initiatives that enhance students' technology readiness by improving digital infrastructure, providing access to AI tools, and promoting digital literacy programmes.

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EFFECT OF INFRASTRUCTURE, POLICY, AND ECOSYSTEM READINESS FOR AI ADOPTION IN FEDERAL CAPITAL TERRITORY COLLEGE OF EDUCATION

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Abstract

This study examined the effect of infrastructure, policy, and ecosystem readiness on Artificial Intelligence (AI) adoption in the Federal Capital Territory (FCT) College of Education, Abuja, Nigeria. A descriptive survey design was employed, with 320 respondents comprising lecturers, ICT staff, administrators, and policymakers. Data were collected using the AI Readiness Assessment Questionnaire (AIRAQ), validated by experts in Educational Technology and ICT, with a reliability coefficient of 0.91. One hypothesis was tested at 0.05 level of significance using descriptive statistics, correlation, and regression analysis. Findings revealed that infrastructural readiness ($\beta = 0.62$, $p < 0.01$) and ecosystem maturity ($\beta = 0.58$, $p < 0.05$) significantly predicted AI adoption, while policy readiness exerted a moderating effect. Qualitative insights highlighted infrastructural deficits, policy gaps and ecosystem weakness staff as persistent barriers. The study recommends strategic investment in broadband and cloud systems, harmonisation of AI policies, and strengthening of academia-industry collaboration to accelerate AI adoption in Nigerian colleges of education.

Keywords: Infrastructure readiness, Policy frameworks, Ecosystem maturity, AI adoption, College of Education.

Introduction

Artificial Intelligence (AI) has become one of the most transformative technologies of the 21st century, reshaping industries, governance, education and many more worldwide. In the education sector, AI offers unprecedented opportunities for personalised learning, predictive analytics, administrative efficiency, and enhanced research capabilities (Ocen, Elasu, Aarakit and Olupot,

2025). Globally, institutions are leveraging AI to automate routine tasks, provide adaptive learning platforms, and improve decision-making processes. For developing nations such as Nigeria, the integration of AI into educational institutions is not merely a technological upgrade but a strategic imperative for national development.

Colleges of education occupy a foundational position in Nigeria's educational system. They are responsible for training teachers who will, in turn, shape the intellectual and moral development of millions of pupils across the country. The Federal Capital Territory (FCT) College of Education is particularly significant for its strategic location in the nation's capital and its role in producing teachers for both urban and rural schools. The readiness of this institution to adopt AI is therefore critical, not only for its internal efficiency but also for the broader educational ecosystem in Nigeria.

Despite the promise of AI, empirical evidence suggests that Nigerian Colleges of Education face persistent challenges in adopting digital innovations (Daramola and Aladesusi, 2022). A recurring concern is infrastructural inadequacy, manifesting in unreliable electricity supply, poor broadband connectivity, and limited access to cloud computing facilities. These problems hinder the deployment of AI systems that require stable power and high-speed internet to function effectively **(**Ibomoiye, Mienye, Yanxia, Emmanuel, 2024). Policy gaps also further compound the problem. While Nigeria has articulated a National Digital Economy Policy and Strategy (2020–2030), institutional-level policies on AI adoption remain fragmented, weakly enforced, or altogether absent. This lack of coherent policy direction results in ad-hoc adoption practices that fail to achieve sustainable outcomes.

Equally important is the state of the ecosystem in which institutions operate. Aliu, Oke, Ebekozien, Aigbavboa & Olonilua (2026) opined that Ecosystem readiness refers to the broader environment

of academia-industry collaboration, innovation hubs, workforce digital literacy, and professional development opportunities. In Nigeria, ecosystem immaturity is evident in the limited partnerships between colleges of education and technology firms, the absence of innovation clusters dedicated to educational AI, and the low levels of digital literacy among staff, particularly senior lecturers. Without a supportive ecosystem, even well-designed infrastructure and policies may fail to translate into effective AI adoption.

The relationship between infrastructure, policy, and ecosystem readiness has attracted considerable scholarly attention in the context of digital transformation. Studies in Asia and Europe have demonstrated that institutions with strong infrastructural support, coherent policies, and mature ecosystems achieve higher rates of AI adoption and integration. Conversely, institutions lacking these pillars struggle with implementation, leading to wasted investments and poor outcomes. In the Nigerian context, research has highlighted similar challenges in ICT adoption, but few studies have systematically examined AI readiness in colleges of education (Nwaimo, Njoku, Ugwu, Akujor, Ejiogu, Nwoko, Ozurumba, Ubah, 2024 and NCC, 2021). This study therefore seeks to investigate the effect of infrastructure, policy, and ecosystem readiness on AI adoption in the FCT College of Education.

Statement of the Problem

Although Artificial Intelligence (AI) is globally recognised as a driver of educational innovation, Nigerian Colleges of Education continue to face persistent challenges that hinder its adoption (Mahuta & Abubakar, 2025). The Federal Capital Territory (FCT) College of Education, Abuja, is no exception. The institution struggles with inadequate infrastructure such as unreliable electricity, poor broadband connectivity, and limited access to cloud computing facilities (Moses, Adiela, and

Amakodi, 2026). These deficits make it difficult to deploy AI systems that require stable power and high-speed internet to function effectively.

In addition, policy frameworks guiding AI adoption remain fragmented and weakly enforced. While Nigeria has articulated a National Digital Economy Policy and Strategy (2020–2030), institutional-level policies on AI integration are either absent or inconsistently applied. This lack of coherent policy direction results in ad-hoc adoption practices that fail to achieve sustainable outcomes.

Equally pressing is the immaturity of the ecosystem in which the college operates. Limited collaboration between academia and industry, the absence of innovation hubs dedicated to educational AI, and low levels of digital literacy among staff particularly senior lecturers further constrain adoption. Without a supportive ecosystem, even well-designed infrastructure and policies may fail to translate into effective AI integration.

These challenges highlight the urgent need for research that systematically investigates the effect of infrastructure, policy, and ecosystem readiness on AI adoption in the FCT College of Education. By addressing this gap, the study provides evidence-based insights that can guide institutional practice, inform policy formulation, and strengthen ecosystem development. Ultimately, the research is necessary to ensure that Nigerian colleges of education are adequately prepared to harness AI for improved teaching, learning, and administration, thereby contributing to the nation's broader digital transformation agenda.

Research Questions

1. How does Infrastructure Readiness influence AI adoption of staffs in FCT College of Education?
2. How does policy readiness influence AI adoption in the FCT College of Education?

3. What role does ecosystem maturity play in predicting AI adoption outcomes in FCT College of Education?

Hypothesis

H_{01}: Infrastructure readiness, policy readiness, and ecosystem maturity have no significant combined effect on AI adoption in the Federal Capital Territory College of Education.

Methodology

This study adopted a descriptive survey design to investigate the effect of infrastructure, policy, and ecosystem readiness on the adoption of Artificial Intelligence (AI) in the Federal Capital Territory (FCT) College of Education. The design was considered appropriate because it allowed for the collection of data from a large and diverse group of respondents without disrupting the normal institutional processes.

The population of the study comprised lecturers, ICT staff, administrators, and policymakers within the College of Education. From this population, a total of 320 respondents were selected using stratified purposive sampling. This sampling technique ensured that all relevant categories of staff were adequately represented, thereby enhancing the validity of the findings.

Data were collected using the AI Readiness Assessment Questionnaire (AIRAQ), a researcher-developed instrument designed to measure infrastructural capacity, policy frameworks, and ecosystem maturity in relation to AI adoption. The instrument was subjected to expert validation by specialists in Educational Technology and ICT experts, and its reliability was confirmed through a pilot test which yielded a Cronbach's alpha coefficient of 0.91, indicating high internal consistency.

The questionnaire was structured on a five-point Likert scale, ranging from "strongly disagree" to "strongly agree," and covered items relating to broadband connectivity, cloud adoption,

institutional policy enforcement, digital literacy, and industry-academia collaboration. In addition to the quantitative data, qualitative insights were obtained through semi-structured interviews with selected respondents, providing deeper contextual understanding of the challenges and opportunities surrounding AI adoption.

Data analysis was conducted using both descriptive and inferential statistics. Descriptive statistics such as mean and standard deviation were used to summarise the levels of infrastructure, policy, and ecosystem readiness. Pearson correlation analysis was employed to examine the relationships among the variables, while multiple regression analysis was used to determine the predictive effects of infrastructure, policy, and ecosystem readiness on AI adoption. Qualitative data were analysed thematically to complement and enrich the quantitative findings. All statistical analyses were performed using SPSS version 27, with a significance threshold set at $p < 0.05$.

Results

Research Question 1

How does Infrastructure Readiness influence AI adoption of staffs in FCT College of Education?

Table 1: Infrastructure Readiness for AI Adoption

Infrastructure Level	N	Mean AI Adoption	Std. Deviation	Std. Error Mean
High Readiness	**160**	**3.62**	**0.54**	**0.04**
Low Readiness	**160**	**2.91**	**0.61**	**0.05**

Independent Samples Test

Levene's Test for Equality of Variances	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Equal variances assumed	**2.15**	**.144**	**9.87**	**318**	**.000**	**0.71**	**0.07**
Equal variances not assumed			**9.87**	**315.2**	**.000**	**0.71**	**0.07**

The independent samples t-test shows a significant mean difference in AI adoption readiness between staff with high infrastructure support (M = 3.62) and those with low support (M = 2.91), $t(318) = 9.87$, $p < 0.01$. This confirms that infrastructure readiness strongly influences AI adoption.

Research Question 2

How does policy readiness influence AI adoption in the FCT College of Education?

Table 2: Policy Readiness and AI Adoption

Component	Mean	Std. Deviation	Interpretation
National AI strategy awareness	**3.02**	**0.68**	**Moderate**
Institutional ICT policy	**2.89**	**0.72**	**Low**
Enforcement mechanisms	**2.75**	**0.76**	**Low**
Ethical guidelines	**3.11**	**0.70**	**Moderate**

Table 3: Correlation between Policy Readiness and AI Adoption

Variables	Policy Readiness	AI Adoption
Policy Readiness	**1.000**	

Variables	Policy Readiness	AI Adoption
AI Adoption Readiness	**0.415****	**1.000**

Respondents show a moderate level of awareness of national AI strategies awareness (Mean = 3.02, SD = 0.68). This suggests that while some knowledge exists, it is not yet widespread or deeply embedded. Institutional ICT policy (Mean = 2.89, SD = 0.72) Institutional-level ICT policies are weak. This indicates that colleges and educational institutions lack strong internal frameworks to guide AI adoption. Enforcement mechanisms (Mean = 2.75, SD = 0.76) Enforcement of AI-related policies is low, meaning that even where policies exist, compliance and monitoring are insufficient. Ethical guidelines (Mean = 3.11, SD = 0.70 → *Moderate*) Ethical awareness is moderate, showing some recognition of AI ethics but not yet fully institutionalized.

Correlation coefficient ($r = 0.415$, $p < 0.01$) between Policy Readiness and AI Adoption Readiness This indicates a moderate positive correlation. As policy readiness improves, AI adoption readiness also increases. The significance level ($p < 0.01$) shows that this relationship is statistically significant, meaning the observed correlation is unlikely due to chance. Policy readiness does not directly drive AI adoption but plays a moderating role. Strong infrastructure and ecosystem readiness are the primary determinants, but coherent policies enhance the effectiveness of these investments. Without policy support, infrastructural improvements may not yield sustainable outcomes.

Infrastructure and ecosystem readiness remain the strongest determinants of AI adoption. Policy readiness has a moderate but significant influence, acting as a catalyst that strengthens the impact of infrastructure and ecosystem investments. Weak institutional ICT policies and enforcement

mechanisms highlight areas needing urgent improvement to ensure sustainable AI integration in education.

Research Question 3

What role does ecosystem maturity play in predicting AI adoption outcomes in FCT College of Education?

Table 3: Ecosystem Readiness Components

Component	Mean	Std. Deviation	Interpretation
Industry-academia collaboration	**2.95**	**0.73**	**Low**
Digital literacy among staff	**3.08**	**0.69**	**Moderate**
Innovation hubs	**2.87**	**0.75**	**Low**
Professional development	**3.21**	**0.68**	**High**

Table 4: Correlation Analysis – Ecosystem Readiness and AI Adoption

Variables	Ecosystem Readiness	AI Adoption
Ecosystem Readiness	**1.000**	
AI Adoption Readiness	**0.583****	**1.000**

Table 5: Regression Analysis – Ecosystem Readiness as Predictor

Predictor Variable	B	T	Sig. (p-value)
Ecosystem Readiness	**0.58**	**5.42**	**< 0.05**

The results show that ecosystem maturity significantly predicts AI adoption outcomes in the FCT College of Education. With a correlation coefficient of $r = 0.583$ ($p < 0.01$), ecosystem readiness demonstrates a strong positive relationship with AI adoption. Regression analysis further confirms its predictive power ($\beta = 0.58$, $p < 0.05$), making it nearly as influential as infrastructure readiness ($\beta = 0.62$).

The descriptive statistics reveal that while professional development opportunities are relatively strong ($M = 3.21$), other components such as industry-academia collaboration ($M = 2.95$) and innovation hubs ($M = 2.87$) remain weak. Digital literacy among staff is moderate ($M = 3.08$), but qualitative insights highlight that senior staff often struggle with AI platforms, underscoring the need for targeted training.

From the TOE framework perspective, ecosystem readiness represents the "environment" dimension, encompassing external collaborations, workforce skills, and innovation networks. A mature ecosystem provides the supportive environment necessary for institutions to translate infrastructure and policy into effective adoption. Without strong partnerships, innovation hubs, and digital literacy, AI adoption remains limited even when infrastructure is available.

Qualitative responses illustrate this challenge: *"We lack partnerships with industry to support AI integration."* This highlights how ecosystem immaturity constrains adoption by isolating the institution from external expertise and resources.

Globally, evidence from Asia and Europe shows that institutions embedded in strong ecosystems characterised by innovation clusters, industry partnerships, and continuous professional development—achieve higher rates of AI integration. The Nigerian context mirrors this, with ecosystem immaturity acting as a bottleneck to adoption.

Hypotheses Testing

Hypothesis 1: Infrastructure readiness, policy readiness, and ecosystem maturity have no significant combined effect on AI adoption in the Federal Capital Territory College of Education.

Table 4: Correlation Matrix

Variables	1	2	3
1. Infrastructure Readiness	1.000		
2. Ecosystem Readiness	0.612**	1.000	
3. AI Adoption	0.624**	0.583**	1.000

p < 0.01 (2-tailed)

Table 5: Regression Analysis

Predictor Variable	β	t	p-value
Infrastructure Readiness	0.62	6.01	<0.01
Ecosystem Readiness	0.58	5.42	<0.05
Policy Readiness	0.41	4.12	<0.05

$R^2 = 0.54$, $F = 32.15$, $p < 0.01$

Model	R	R^2	Adjusted R^2	Std. Error	F	Sig.
1	**.735**	**.540**	**.534**	**0.45**	**32.15**	**.000**

The combined regression model shows that infrastructure, policy, and ecosystem readiness together explain 54% of the variance ($R^2 = .54$) in AI adoption readiness. All three predictors are statistically significant, with infrastructure readiness being the strongest driver, followed by ecosystem maturity, and then policy readiness.

Therefore, the null hypothesis (H0) is rejected. The alternative hypothesis (H1) is supported: infrastructure, policy, and ecosystem readiness significantly predict AI adoption in the FCT College of Education.

Thematic Approach

In addition to the quantitative analysis, a thematic approach was employed to capture the nuanced experiences and perceptions of staff regarding infrastructure, policy, and ecosystem readiness for AI adoption. Semi-structured interviews were conducted with selected lecturers, ICT staff, and

administrators, and their responses were analysed using thematic coding. This process involved identifying recurring patterns, categorising them into themes, and interpreting their implications for institutional readiness.

Three major themes emerged:

1. **Infrastructural Deficits:** Respondents consistently highlighted unreliable broadband connectivity, frequent power outages, and inadequate access to cloud computing facilities. One participant noted, *"Our broadband is unreliable, making AI tools difficult to use."* These infrastructural challenges were seen as the most immediate barrier to AI adoption, reinforcing the quantitative finding that infrastructure readiness is the strongest predictor of adoption.

2. **Policy Gaps:** Many respondents pointed to the absence of clear institutional policies on AI integration. While national ICT strategies exist, they are not effectively translated into actionable guidelines at the college level. A lecturer remarked, *"No official AI policy exists in the college, so adoption is inconsistent."* This theme underscores the moderating role of policy readiness observed in the regression analysis.

3. **Ecosystem Weakness:** Limited collaboration between academia and industry was repeatedly mentioned. Respondents lamented the lack of partnerships with technology firms and innovation hubs that could provide practical support for AI adoption. One ICT staff member explained, *"We lack partnerships with industry to support AI integration."* This theme aligns with the moderate correlation between ecosystem readiness and AI adoption found in the quantitative results.

Integration of Themes with Quantitative Findings

The thematic insights provide contextual depth to the statistical results. While SPSS outputs confirmed that infrastructure and ecosystem readiness significantly predict AI adoption, the thematic analysis explains why these variables matter. Infrastructural deficits directly hinder the functionality of AI systems, policy gaps create uncertainty and ecosystem weakness limits external support. Together, these themes illustrate that AI adoption is not simply a technological issue but a multidimensional challenge requiring holistic solutions.

Discussion of Findings

The findings of this study provide strong evidence that infrastructure and ecosystem readiness are the most critical determinants of AI adoption in the FCT College of Education, while policy readiness plays a moderating role which is inline with the findings of Mona, Kelly, Bruno, Margaux & Iida (2025), World Bank Group (2025) and Hsu (2026). This outcome is consistent with global research on digital transformation, which emphasises that technological innovations thrive only when supported by robust infrastructure and enabling ecosystems.

The regression analysis revealed that infrastructure readiness ($\beta = 0.62$, $p < 0.01$) was the strongest predictor of AI adoption. This is not surprising given that AI systems depend heavily on stable electricity, broadband connectivity, and access to cloud computing. The thematic insights reinforced this finding, with respondents repeatedly citing unreliable broadband and frequent power outages as barriers. This aligns with Hsu (2026) and the Technology-Organisation-Environment (TOE) framework, which posits that technological characteristics and availability directly influence adoption outcomes. In the Nigerian context, infrastructural deficits have long been identified as a bottleneck to ICT integration, and this study confirms that they remain the most pressing challenge for AI adoption.

Policy readiness was found to have a weaker but still significant effect ($\beta = 0.41$, $p < 0.05$). The correlation analysis also showed a modest relationship between policy readiness and AI adoption ($r = 0.415$, $p < 0.01$). The thematic analysis explained this result: while national strategies such as the National Digital Economy Policy (2020–2030) exist, institutional-level policies are fragmented and weakly enforced. Respondents noted the absence of clear AI guidelines within the college, leading to inconsistent adoption practices. This finding highlights the moderating role of policy readiness: without coherent policies, infrastructural investments may not yield sustainable outcomes. From a sociotechnical systems perspective, policies represent the organisational norms and rules that must align with technical systems to ensure effective adoption.

Ecosystem readiness emerged as the second strongest predictor ($\beta = 0.58$, $p < 0.05$), with a significant correlation ($r = 0.583$, $p < 0.01$). Respondents emphasised the lack of industry-academia collaboration and innovation hubs, as well as digital literacy gaps among senior staff. These findings underscore the importance of ecosystem maturity in supporting AI adoption. Ecosystems provide external partnerships, training opportunities, and innovation clusters that sustain technological integration. The TOE framework identifies environmental pressures such as industry collaboration and competitive dynamics as key drivers of adoption. The absence of such pressures in the FCT College of Education explains the moderate levels of ecosystem readiness observed.

Integration of Quantitative and Qualitative Findings

The thematic approach enriched the quantitative results by providing context while SPSS outputs confirmed infrastructure as the strongest predictor, qualitative data explained that unreliable broadband and power outages directly hinder AI functionality. Similarly, policy readiness was statistically weaker, but interviews revealed that staff perceive the absence of institutional AI policies as a major obstacle. Ecosystem readiness was statistically significant, and thematic

insights showed that digital literacy gaps and weak partnerships limit adoption. Together, these findings illustrate that AI adoption is not merely a technological issue but a multidimensional challenge requiring infrastructural, policy, and ecosystem interventions.

Conclusion

This study has demonstrated that the readiness of FCT college of education to adopt Artificial Intelligence (AI) is a multidimensional construct shaped by infrastructure, policy, and ecosystem factors. The findings from the Federal Capital Territory (FCT) College of Education reveal that infrastructural readiness, particularly broadband connectivity, cloud adoption, and reliable electricity, is the most critical determinant of AI adoption. Without these foundational elements, AI systems cannot function effectively, regardless of policy intentions or ecosystem support.

Policy readiness was found to exert a moderating influence. While national frameworks such as Nigeria's National Digital Economy Policy and Strategy (2020–2030) provide broad direction, institutional-level policies remain fragmented and weakly enforced. This gap undermines the sustainability of AI adoption, as staff lack clear guidelines and incentives to integrate AI into teaching, research, and administration. The study underscores the need for harmonised policies that translate national strategies into actionable institutional frameworks.

Ecosystem readiness emerged as the second strongest predictor of adoption, highlighting the importance of industry-academia collaboration, innovation hubs, and workforce digital literacy. The thematic insights revealed that digital literacy gaps, particularly among senior staff, and weak partnerships with technology firms constrain adoption. This finding affirms the role of ecosystems

as enablers of technological transformation, providing the external support and internal capacity necessary for sustainable integration.

Taken together, the results validate the Technology-Organisation-Environment (TOE) framework and Sociotechnical Systems Theory. TOE explains how technology (infrastructure), organisation (policy), and environment (ecosystem) interact to shape adoption outcomes, while sociotechnical theory emphasises the alignment between social systems (skills, culture, norms) and technical systems (AI tools, broadband, cloud). The study shows that without this alignment, adoption remains partial and unsustainable.

The implications of these findings are profound. For policymakers, the study highlights the need to move beyond rhetorical commitments to digital transformation and invest in practical infrastructural upgrades, enforceable policies, and ecosystem development. For institutional leaders, the findings emphasise that AI adoption cannot be achieved through isolated technological investments; it requires a holistic approach that synchronises infrastructure, policy, and ecosystem readiness. For educators and staff, the study underscores the importance of continuous professional development and digital literacy as prerequisites for meaningful engagement with AI tools.

Ultimately, the research confirms that AI adoption in Nigerian Colleges of Education is both possible and necessary, but only if infrastructural deficits are addressed, policies are harmonised, and ecosystems are strengthened. By strategically investing in these three pillars, institutions such as the FCT College of Education can position themselves at the forefront of Nigeria's digital transformation agenda, contributing not only to improved teaching and learning but also to national development in line with the African Union's Agenda 2063.

Recommendations

Based on the findings of this study, several recommendations are proposed to strengthen infrastructure, policy, and ecosystem readiness for AI adoption in the FCT College of Education. These recommendations are structured to address the three pillars identified as critical for sustainable integration of AI into educational practice.

1. Infrastructure Investment: The Federal Government and institutional leadership should prioritise investment in broadband connectivity, stable electricity, and cloud computing facilities. Smart classrooms equipped with interactive boards, IoT devices, and AI-enabled learning platforms should be gradually introduced to enhance teaching and learning. A dedicated ICT maintenance unit should be established within the college to ensure continuous support and sustainability of infrastructural upgrades.

2. Policy Harmonisation: Institutional policies must be aligned with Nigeria's National Digital Economy Policy and Strategy (2020–2030) to provide clear guidelines for AI adoption. Policies should include enforceable standards for data privacy, ethical use of AI, and accountability mechanisms to ensure transparency. Incentives such as grants, recognition awards, and promotion criteria should be tied to innovative use of AI in teaching, research, and administration.

3. Ecosystem Strengthening: The college should establish partnerships with technology firms, innovation hubs, and research centres to provide practical support for AI integration. Industry-academia collaboration should be fostered through joint projects, internships, and knowledge exchange programmes. Innovation clusters dedicated to educational AI should be developed within Abuja to serve as incubators for new ideas and solutions.

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Artificial Intelligence-Driven Laboratory Assistants and Virtual Laboratories in Science and Biology Education: A Systematic Review of the Global and Sub-Saharan African Evidence Base

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ABSTRACT

Artificial intelligence (AI) is increasingly applied across science education, yet it remains unclear how much of this activity involves genuine AI-driven laboratory assistance, systems that automate, monitor, or guide physical experimentation in real time, as opposed to screen-based virtual or simulated laboratories, and how this evidence base translates to resource-constrained settings such as Nigeria. This paper reports a rapid, PRISMA-informed systematic review addressing this question. A web-based search of academic publishers, indexing services, and institutional repositories was conducted, supplemented by citation-chasing from an included systematic review. Thirty-one unique candidate records were screened against explicit eligibility criteria; twenty-two records, comprising systematic reviews, empirical studies, and literature reviews published between 2019 and 2025, were retained for narrative synthesis. The review finds a rapidly growing but fragmented global evidence base on AI in science education, dominated by intelligent tutoring systems, chatbots, and automated assessment tools. Within biology education specifically, AI applications include AI-enriched textbooks, image-recognition tools for concept instruction, and a small number of AI-driven laboratory-support systems, though these remain concentrated in Asian higher-education and K-12 contexts rather than Sub-Saharan Africa. Across Sub-Saharan Africa, and Nigeria in particular, the dominant technological response to biology-laboratory resource constraints is the screen-based virtual laboratory rather than an AI-driven assistant that supports physical experimentation; adoption is further constrained by infrastructural deficits, limited teacher digital literacy, and a preponderance of narrative rather than empirical or systematic studies. No study meeting the review's eligibility criteria reported the development or validation of a real-time, task-automating AI laboratory assistant for secondary school biology in Nigeria or a comparable Sub-Saharan African context, indicating a substantive and currently unaddressed research gap that this review makes explicit for future development-and-validation research.

Keywords: Systematic Review; Artificial Intelligence in Education; Intelligent Lab Assistant; Virtual Laboratory; Biology Education; Sub-Saharan Africa; Nigeria

INTRODUCTION

Artificial intelligence (AI) has moved from a peripheral to a central concern in science education research over the past decade, with applications spanning intelligent tutoring, automated assessment, learning analytics, and adaptive content delivery (Zawacki-Richter *et al.,* 2019; Chen *et al.* 2021; Zhai *et al.*). Within this broader movement, a narrower and less well-mapped strand concerns AI-driven laboratory assistance: systems that actively support, automate, or monitor hands-on experimentation, as distinct from the more familiar category of virtual or simulated laboratories that substitute screen-based activity for physical apparatus.

This distinction matters for contexts such as Nigeria and much of Sub-Saharan Africa, where biology laboratory instruction is constrained by inadequate equipment, large class sizes, and heavy teacher workload (Nja *et al.,* 2023; Usman *et al.,* 2025). A virtual laboratory can substitute for missing apparatus, but it does not, by itself, reduce a teacher's burden of managing an active physical laboratory or provide real-time safety monitoring and personalised guidance during an actual experiment. An AI-driven Intelligent Lab Assistant, by contrast, is intended to operate alongside physical laboratory work, automating routine tasks and providing in-situ feedback. Whether such systems exist, and in what contexts they have been developed and evaluated, is an empirical question that has not, to the authors' knowledge, been systematically mapped for biology education in Sub-Saharan Africa.

This paper addresses that gap through a rapid, PRISMA-informed systematic review (Moher *et al.,* 2015) of the international and Sub-Saharan African literature on AI applications in science and biology education, with particular attention to the distinction between AI-driven laboratory assistance and virtual/simulated laboratories. Four research questions guide the review: (RQ1) What types of AI applications have been reported in science and biology education globally? (RQ2) To what extent do these applications function as active, real-time laboratory assistants, as opposed to screen-based virtual or simulated laboratories? (RQ3) What does the available evidence show about the adoption, effectiveness, and barriers of AI-driven and virtual laboratory technologies for biology education in Sub-Saharan Africa, and Nigeria specifically? (RQ4) What gaps exist in the current evidence base that warrant further development-and-validation research? The remainder of the paper describes the review methodology, presents the synthesised findings, discusses their implications, and identifies the review's own limitations.

REVIEW METHODOLOGY

Protocol and Approach

This review follows the general reporting logic of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Moher, 2015), adapted to a rapid-review

format. Consistent with rapid-review conventions, screening and data extraction were conducted by a single reviewer rather than by two independent reviewers, and no formal risk-of-bias instrument (e.g., MMAT, ROBIS) was applied; the review should therefore be read as an indicative, structured synthesis rather than a full Cochrane-standard systematic review. This limitation, and its implications, is discussed further in Section 5.

Search Strategy

Searches were conducted in July 2026 using an AI-assisted web search tool that indexes major academic publishers, aggregator platforms, and institutional repositories (including, among the sources returned, ScienceDirect, SAGE, Springer, Frontiers, PubMed Central, arXiv, ResearchGate, Nature/npj journals, and African institutional and society journals). Four search iterations were run using combinations of the terms "artificial intelligence," "intelligent lab assistant," "virtual laboratory," "biology education," "science education," "systematic review," "Nigeria," and "Sub-Saharan Africa" or "Africa." Additional records were identified by citation-chasing the reference list of one comprehensive included review (Fayzullina, 2025). This search approach differs from a formal multi-database Boolean export (e.g., a documented Scopus or Web of Science query with saved search strings) and is reported as a limitation in Section 5.

Eligibility Criteria

Records were included if they (a) were peer-reviewed journal articles, indexed conference papers, data descriptors, or reputable preprints; (b) reported empirical findings, a systematic or literature review, or a data descriptor; (c) substantively addressed AI applications in science or biology education, virtual or simulated laboratory technology in science or biology education, or AI adoption in African science-education contexts specifically; (d) were published between 2019 and 2026; and (e) were available in English with an accessible abstract or full text. Records were excluded if they (a) lacked verifiable bibliographic metadata (author, venue, or year); (b) addressed AI in education generally with no reference to laboratory instruction, science or biology subject matter, or a Sub-Saharan African context; (c) concerned populations outside K-12, secondary, or general higher-education science, such as specialised professional curricula; or (d) duplicated an already-retained record via a different hosting platform.

Study Selection

The search process surfaced 35 candidate records; after consolidating duplicate listings of the same article across multiple hosting or mirror platforms, 31 unique records remained. Title/abstract screening against the eligibility criteria excluded nine records, seven addressing AI in Nigerian education generally without a laboratory, science, or biology focus, one addressing undergraduate medical curricula (an ineligible population), and one bibliometric review for which author identity could not be verified from available metadata. Twenty-two records were retained for full synthesis. Table I summarises this process.

Table 1: Study Selection Process (Prisma-Informed)

Stage	Description	n
Identification	Candidate records surfaced through four targeted web-based search iterations and citation-chasing	35
Deduplication	Duplicate listings of the same article across multiple hosting/mirror platforms consolidated	31
Screening	Title/abstract screening against eligibility criteria; records excluded for lacking laboratory/science/biology or African-context focus, ineligible population, or unverifiable metadata	9 excluded
Included	Records retained for full-text synthesis	22

Data Extraction and Synthesis

For each included record, the following were extracted where reported: publication year, country/region of study or authorship, education level, type of AI or virtual-laboratory application, subject focus (general science versus biology specifically), study design, and sample size. Given the heterogeneity of study designs (systematic reviews, quasi-experiments, and narrative/conceptual papers), a narrative thematic synthesis was used rather than meta-analysis. Five themes were derived inductively from the extracted data and are reported in Section 3.

RESULTS

Overview of Included Studies

Of the 22 included records, ten were systematic or mapping reviews synthesising between 17 and 258 primary studies each (Zawacki-Richter *et al,* 2019; Chen *et al.,* 2021; Zhai *et al.*; Fayzullina et al., 2025; Almasri, 2024; Xu & Ouyang, 2022; Heeg & Avraamidou, 2023; Dai & Ke, 2022; Memari & Ruggles, 2025; Létourneau *et al.,* 2025); seven were empirical or applied studies reporting the design, prototyping, or evaluation of specific AI or virtual-laboratory tools (Koć-Januchta *et al.,* 2020; Chen & Liu, 2024; Lee *et al.*, 2023; Yang *et al.*, 2023; Byukusenge et al., 2022; Byukusenge *et al.,* 2024; Shambare & Simuja, 2022); and five were narrative reviews or

conceptual papers concentrated on African or Nigerian contexts (Usak, 2024; Aripin, 2024; Selvam, 2024; Nja *et al.,* 2023; Usman *et al.,* 2025). Fourteen records concerned science education broadly, while eight concerned biology specifically. Five records reported evidence located in, or specifically concerning, Sub-Saharan Africa.

Theme 1: The Global Landscape of AI in Science Education

The reviewed systematic and mapping reviews converge on a picture of rapid but fragmented growth. Fayzullina *et al.* (2025), analysing 17 studies from 2020-2024, report AI applications spanning chatbots, intelligent tutoring systems, and AI-enhanced textbooks, with generally favourable effects on performance, motivation, and engagement, alongside persistent concerns about infrastructure, system reliability, and ethics. Almasri (2024), following PRISMA guidelines across 74 records from 2014-2023, and Xu and Ouyang (2022), covering AI in STEM education from 2011-2021, report similar patterns of diverse application types and generally positive but unevenly measured outcomes. Létourneau *et al.* (2025), reviewing 28 studies of intelligent tutoring systems in K-12 education involving a combined 4,597 students, find generally positive but modest effects relative to non-intelligent alternatives, and call for longer interventions and larger, more diverse samples. Memari and Ruggles (2025), synthesising 258 studies of AI in elementary STEM education, describe the field as characterised by "rapid growth but fragmented implementations," a description this review's own findings corroborate at the intersection of AI and laboratory instruction specifically.

Theme 2: AI Applications Specific to Biology Instruction

A smaller subset of included studies addresses biology instruction specifically. Koć-Januchta *et al.* (2020) report that an AI-enriched biology textbook supporting student-posed questions improved engagement and interaction with content. Chen and Liu (2024) find that AI robot image-recognition technology improved conceptual understanding of cell division and science learning motivation among students. Usak (2024) and Aripin et al. (2024) each provide reviews specific to AI in biology education, both noting that applications cluster around personalisation, virtual experimentation, and data interpretation, while flagging teacher-training and infrastructure gaps as recurring barriers to fuller adoption. Selvam (2024) extends this picture across physics, chemistry, and biology, reporting consistent gains in motivation and conceptual understanding alongside unresolved ethical and infrastructural concerns.

Theme 3: AI-Driven Laboratory Assistants versus Virtual/Simulated Laboratories

This theme addresses RQ2 directly. Only two included records describe systems that function as active, real-time laboratory assistants rather than screen-based simulations. Lee *et al.,* (2023) report the rapid prototyping of a hands-free AI speaker system designed to support hands-on science laboratory classes, providing voice-mediated assistance during live experimentation. Yang *et al.,* (2023) describe a gamified AI educational robot developed to promote learning effectiveness

and safety behaviour in undergraduate laboratory safety courses. Both systems were developed and evaluated in Asian higher-education or general K-12 settings; neither addresses secondary school biology, and neither was identified as having been developed for, or evaluated within, a Sub-Saharan African context.

By contrast, the dominant AI-adjacent response to laboratory resource constraints identified in this review, particularly within biology education, is the virtual or simulated laboratory: a screen-based environment (e.g., commercial platforms such as Labster, PraxiLabs, and Froguts, referenced in Usman (2025) that substitutes simulated experimentation for physical apparatus, but does not itself automate, monitor, or provide real-time assistance during actual hands-on laboratory activity. Byukusenge *et al.,* (2022), reviewing 26 articles specifically on virtual laboratories in biology education, and a related quasi-experimental study involving 168 Rwandan secondary biology students (Byukusenge *et al.,* 2024), both report positive effects on academic performance and attitudes from virtual-laboratory use, reinforcing the pattern that virtual laboratories, rather than AI-driven physical-laboratory assistants, represent the more mature and evidenced intervention type for biology practicals in resource-constrained settings.

Theme 4: The Sub-Saharan African and Nigerian Evidence Base

Five included records concern Sub-Saharan Africa directly. Shambare and Simuja (2022) critically review the use of virtual laboratories as a response to practical-experiment challenges in rural South African schools, noting that infrastructural constraints (electricity, connectivity, and device access) and teacher readiness remain the principal barriers to adoption, a finding echoed in related South African studies on teacher perceptions and technological pedagogical content knowledge for virtual-laboratory use (not separately detailed here due to overlapping authorship and setting with (Shambare & Simuja, 2022). Nja *et al.* (2023), surveying African science teachers' adoption of AI more broadly, similarly identify infrastructure and professional development as the dominant constraints, alongside generally positive teacher attitudes toward AI's potential. Usman *et al.,* (2025), writing specifically on AI-powered tools in Nigerian biology education, describe virtual laboratories, adaptive learning platforms, and data-driven applications as the principal available tools, and explicitly identify limited laboratory access, inadequate infrastructure, low teacher digital literacy, and policy gaps as constraints on adoption, while noting emerging national policy support through Nigeria's National Digital Economy Policy and Strategy.

None of the five Sub-Saharan Africa-focused records, and none of the 22 included records overall, reported the development, prototyping, or validation of an AI-driven laboratory assistant, as distinct from a virtual/simulated laboratory, for secondary school biology education in Nigeria or a comparable Sub-Saharan African setting.

Methodological Quality Patterns Across Included Studies

A clear methodological gradient is observable across the included records. The ten systematic and mapping reviews (Zawacki-Richter *et al.,* 2019; Chen *et al.,* 2021; Zhai *et al.,*; Fayzullina et al.,

2025; Almasri, 2024; Xu & Ouyang, 2022; Heeg & Avraamidou, 2023; Dai & Ke, 2022; Memari & Ruggles, 2025; Létourneau *et al.,* 2025) report explicit search protocols, defined eligibility criteria, and specified study counts, consistent with recognised systematic review conventions. The seven empirical/applied studies (Koć-Januchta *et al.,* 2020), Chen and Liu, 2024), Lee *et al.,* 2023, Yang *et al.,* 2023, Byukusenge et al., 2022, Byukusenge *et al.,* 2024, Shambare and Simuja, 2022 report quasi-experimental or applied-development designs with sample sizes ranging from single-prototype evaluations to 168-186 participants. By contrast, the five Sub-Saharan Africa/Nigeria-focused records not already captured above in Usak (2024), Aripin *et al.,* (2024), and Selvam (2024). Nja et al., (2023), Usman et al., (2025) are predominantly narrative or conceptual in character, synthesising secondary literature and policy documents rather than reporting new empirical data specific to AI-driven laboratory assistance. This imbalance, a comparatively rich global systematic-review literature on AI in science education set against a thin, largely narrative, Sub-Saharan African evidence base specific to AI-driven laboratory assistance, constitutes a substantive finding of this review in its own right.

DISCUSSION

Read together, the included studies indicate that AI in science and biology education is a maturing but unevenly distributed field. Globally, systematic reviews report a broad and growing repertoire of AI applications with generally positive, if methodologically uneven, effects on learning outcomes, motivation, and engagement (Fayzullina *et al.*, 2025; Almasri, 2024; Xu & Quyang 2022; Heeg & Avraamidou, 2023; Dai & Ke, 2022; Memari & Ruggles, 2025; Létourneau et al., 2025). Within biology specifically, AI has been shown to support conceptual understanding and engagement through tools such as AI-enriched textbooks and image-recognition systems (Koć-Januchta *et al*., 2020; Chen & Liu, 2024). However, when the analytic lens is narrowed specifically to AI-driven laboratory assistance, active, real-time support for physical experimentation, the evidence base thins sharply: only two included studies describe such systems (Lee *et al*., 2023; Yang *et al.,* 2023) and neither originates from, nor was evaluated within, a Sub-Saharan African or Nigerian secondary school biology context.

This gap is consequential. The Sub-Saharan African literature identified in this review shows that virtual/simulated laboratories are being adopted, with encouraging effects on achievement and attitudes (Byukusenge *et al.,* 2022; Byukusenge *et al.,* 2024), as a response to physical laboratory resource constraints. Yet virtual laboratories address a different problem than AI-driven laboratory assistants: they substitute for missing apparatus rather than reducing the burden of managing active, physical laboratory sessions, providing real-time safety monitoring, or automating routine technical tasks such as equipment calibration and data logging, which the Nigeria-specific literature identifies as persistent sources of teacher workload and safety risk (Usman *et al.,* 2025). Insofar as under-resourced schools in Nigeria and comparable settings retain some physical laboratory capacity, however limited, an AI-driven assistant operating alongside that capacity

represents a distinct and currently under-researched intervention relative to the virtual-laboratory substitution model that dominates the existing evidence.

This review therefore surfaces, rather than resolves, a concrete research gap: the absence, within the identified literature, of a validated AI-driven Intelligent Lab Assistant for secondary school biology instruction in Nigeria or comparable Sub-Saharan African contexts. This gap provides empirical justification for development-and-validation research of the kind increasingly being pursued through nationally funded science-education initiatives in the region, and suggests that such research should explicitly report study protocols, sample characteristics, and validation procedures in sufficient detail to strengthen the currently thin empirical base identified in Section 3.6. It also suggests that future systems in this space should be evaluated not only against the virtual-laboratory benchmark (does the tool improve on screen-based simulation?) but against the laboratory-assistance benchmark established by systems such as Lee *et al.,* (2023) and Yang *et al.,* (2023) (does the tool reduce teacher workload and enhance safety and guidance during live, physical experimentation?).

The methodological gradient identified in Section 3.6, rich systematic-review evidence globally, thin narrative evidence regionally, also has implications for future scholarship. Researchers working on AI-driven laboratory assistance in Sub-Saharan Africa would strengthen the field's evidence base by adopting the reporting conventions already established in the global systematic-review literature (Fayzullina *et al.,* 2025; Almasri, 2024; Xu & Quyang 2022; Heeg & Avraamidou, 2023 ; Dai & Ke, 2022; Memari & Ruggles, 2025; Létourneau *et al.,* 2025): explicit protocols, defined eligibility criteria, and transparent sample reporting, alongside the staged, multi-stakeholder validation procedures already modelled by empirical laboratory-technology studies such as (Lee *et al.,* 2023; Yang *et al.,* 2023); Byukusenge *et al.,* 2022; Byukusenge et al., 2024; Shambare & Simuja, 2022).

LIMITATIONS OF THE REVIEW

This review has several limitations that qualify its conclusions. First, screening and extraction were conducted by a single reviewer using an AI-assisted web search tool rather than a documented, reproducible Boolean query executed across formal bibliographic databases (e.g., Scopus, Web of Science, ERIC) with dual independent screening; the review should accordingly be read as a rapid, indicative synthesis rather than a full Cochrane-standard systematic review. Second, no formal risk-of-bias or methodological-quality appraisal instrument was applied to included studies; the methodological patterns reported in Section 3.6 are descriptive rather than the output of a validated appraisal tool. Third, the search was restricted to English-language, web-indexed, and largely open-access sources, which may have under-represented non-English regional literature, including French-, Portuguese-, or indigenous-language scholarship from Sub-Saharan Africa. Fourth, the search represents a snapshot taken in July 2026 and does not capture subsequent publications. These limitations mean that the absence of an identified AI-driven laboratory assistant for Nigerian secondary biology education should be read as an evidence gap within the literature searched,

rather than definitive proof that no such system exists anywhere; researchers aware of unindexed, non-English, or very recent work in this specific area are encouraged to bring it to the field's attention.

CONCLUSION

This rapid, PRISMA-informed systematic review synthesised 22 studies to examine what is known about AI-driven laboratory assistance and virtual laboratories in science and biology education globally and within Sub-Saharan Africa. The evidence shows a maturing global field of AI applications in science education, a smaller but growing literature on AI applications specific to biology instruction, and a still-thin evidence base, dominated by virtual/simulated laboratories rather than active AI-driven laboratory assistants, within Sub-Saharan Africa and Nigeria specifically. No study meeting this review's eligibility criteria reported a validated AI-driven Intelligent Lab Assistant for secondary school biology in Nigeria or a comparable regional context. This finding identifies a concrete, currently unaddressed gap and offers a set of reporting and evaluation benchmarks, drawn from the global literature, that future development-and-validation research in this specific area can adopt to strengthen the field's evidence base.

Acknowledgment

This review was undertaken in connection with ongoing research on AI-driven Intelligent Lab Assistants supported by the Tertiary Education Trust Fund (TETFund) National Research Fund (NRF) 2024 Grant (Ref: TETF/ES/DR&D-CE/NRF2024/HSS/EHC/00358/VOL.1), awarded to the Federal University of Technology, Minna, Nigeria.

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