Future-Ready Learning: Emerging Tech Shaping the Evolution of Computer Science Education

Olugbenga G. Akindoju[1] , Olasunkanmi A. Gbeleyi[2], Esther O. Peter[3], Ebisin, A. Foluso[4], Adeleye J. Adedamola[5], Famuyide J. Alaba[6], Ayinde B. Oyeniran[7]

Lagos State University, Nigeria

DOI: https://doi.org/10.47772/IJRISS.2026.10200378

Received: 19 February 2026; Accepted: 25 February 2026; Published: 12 March 2026

ABSTRACT

With the digital revolution reshaping education globally, computer science education in Nigeria stands at the forefront of this transformation. This study explores innovative teaching and learning methods that leverage emerging technologies to foster creativity, critical thinking, collaboration, and problem-solving among learners. Specifically, it examines the integration of artificial intelligence, virtual and augmented reality, gamified classrooms, and adaptive learning systems within Nigerian computer science education. Employing a mixed method approach, the research combined conceptual analysis with empirical evidence drawn from both Nigerian and international contexts. The reliability of the instrument used was confirmed with a satisfactory reading of 0.72, making it suitable for educational research. Findings reveal that artificial intelligence and virtual reality are widely embraced by learners and instructors, while gamification and collaborative platforms remain underutilized due to infrastructural and cultural barriers. Respondents identified poor internet connectivity, high costs of digital tools, and limited digital skills among educators as the most pressing challenges. This study contributes to the growing body of knowledge by highlighting the realities of technology adoption in Nigerian higher education and emphasizing the importance of learner-centered pedagogy, digital literacy frameworks, and inclusive practices to bridge the gap between theory and practice. Practical recommendations include promoting lifelong learning among professionals, strengthening institutional governance, and investing in affordable digital infrastructure to ensure equitable access. Ultimately, the findings point toward a redesign of computer science education in Nigeria, driven by innovation, inclusivity, and lifelong learning in the digital era.

Keywords: Computer Science Education, Digital Pedagogy, Artificial Intelligence, Gamified Learning, Adaptive Systems, Digital Literacy, Equity

INTRODUCTION AND BACKGROUND

The spurring emergence of new technology and digitalization has made the work of the 21st century more bloodthirsty, and that is why the traditional education process has radically changed its form (Adeba and Gatewood, 2024).To create a workforce that can look ahead, learning institutions need to leverage those skills and capabilities that are distinctly unproven by automation and transition to a model based on high-level cognitive ability, including critical thinking, problem-solving, and creativity (Adeba & Gatewood, 2024; LiesaOrus et al., 2020). Within the digital age, key to reinventing Computer Science Education (CSE) education is the paradigm shift of traditional teacher-centred learners towards network-as-a-platform that allows learning technologies to emerge (Gupta et al., 2021).

Recent additions to CSE are use of sophisticated technologies such as Artificial Intelligence (AI), Machine Learning (ML) and immersive technologies in the course of accommodating the presentation of pedagogical content. Generation AI (Generative AI or GenAI) and Large Language models (LLM) like ChatGPT, Codey, and GitHub Copilot to provide a personalised learning experience, auto-generation of code, and real-time debugging are currently in use (Gaitantzi and Kazanidis, 2025; Oyelere and Aruleba, 2025). These kinds of technologies allow creating AI-native software, where students do not need to be coders, but instead they are AI curators (Gaitantzi and Kazanidis, 2025). Alternatively, abstract concepts are simplified with the help of immersive learning experiences like Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR),

and improve engagement between the student through embodied interaction (Kuhail et al., 2022; Pirker et al., 2020).

The success of these digital interventions is based on the relationship between institutional support and innovation and digital literacy. It has been demonstrated that institutional capacity building encompassing policy-related matters, leaders, and funding has been identified as one of the primary drivers of digital inclusion (Onyia et al., 2023). To use an example, Technological Pedagogical Content Knowledge (TPACK) framework observed that successful teaching comprises of three content knowledge (CK), pedagogical knowledge (PK) and technology knowledge (TK) (Temirkhanova et al., 2024).

The support provided by the institution should not just be infrastructure but ongoing professional development of educators in digital literacy, so that they can be ready to incorporate the use of such tools as Unity or Cisco Packet Tracer into the curriculum (Adeba and Gatewood, 2024, Temirkhanova et al., 2024). Another mechanism that determines the successful adoption of such innovations are the factors which are presented in the Technology Acceptance Model (TAM), which are perceived usefulness and perceived ease of use (Almassaad et al., 2024; Or, 2025).

The international standards of digitally enhanced learning have been focused on the active, inclusive, and student-centred approaches. Students in such countries as Saudi Arabia are real world leaders in the field of GenAI usage, and they are using these tools to brainstorm, analyse data, and summarise literature (Almassaad et al., 2024). The SAMR model (Substitution, Augmentation, Modification, Redefinition) is a universal benchmark of the assessment of infusion of technology into teaching practise, starting with augmentation of the most primitive tools and culminating in the development of the responsibilities that were impossible before (Kuhail et al., 2022; Puentedura, 2010). The collaborative digital tools (such as Microsoft White board and 3D modelling programmes (e.g., Blender and Sketch Up) can be mentioned as the best practises in the context of Kazakhstan: they should be used to promote technical skills and outlook towards entrepreneurship among Generation Z students (Temirkhanova et al., 2024). Equally, the Nigerian research suggests that activity: computer science replugged Interpretations of unplugged activities should be determined to feel like an immersive virtual environment (Pirker et al., 2020).

The reinvention of CSE needs a data-driven and conceptual model, where equity and inclusion are put on harmony with technological reinvention. An integrated framework known as Integrated Modelling of Inclusive Educational Development refers to the cyclic model in which the instructional innovation leads to student engagement, which, in turn, should be supported by inclusive training and alignment of curricular content (Umoke et al., 2025). Inclusion includes meeting the digital divide and infrastructural inequity to guarantee that students with a wide range of socio-economic statuses are given equal access to the broadband and high-quality learning materials and services (Maluleke, 2025; Oyelere & Aruleba, 2025).

Policy Data-based models, including OSMASEM (One-step Meta-analytic Structural Equation Modelling), give information on how people trust AI and can use it to help institutions implement user-friendly policies (Or, 2025). With the help of Learning Analytics (LA) and Educational Data Mining (EDM), educators could track the progress timely, offering specific assistance to at-risk students and making sure that the digital transformation would cause more social equality than widen the existing differences (Adeba and Gatewood, 2024; Manorat et al., 2025). The paper aims at filling these voids by examining conceptual and empirical ways of reinventing learning in the digital age.

Problem Statement

The encouraging innovation of Artificial Intelligence (AI) and online technologies has transformed the spheres of operation of the world, and Computer Science Education (CSE) has been grappling with the mismatch between conventionalised teaching practises and dynamism of the modern labour market (Adeba and Gatewood, 2024; Coroiu et al., 2025). Even though new learning technologies, including Generative AI (GenAI), machine learning (ML), and immersive experiences like Virtual Reality (VR) and Augmented Reality (AR) have a potentially transformative prospect, they lack a consistent place in the curriculum and do not always have a solid pedagogical grounding (Gaitantzi & Kazanidis, 2025; Pirker et al., 2020). The ongoing

education will often decrease the magnitude of these innovations only to tool replacement, as opposed to the opportunity to redefine tasks and involve uncomfortable cognitive efforts (Kuhail et al., 2022).

Barriers to the education process such as insufficient structural support, deficient professional training, and low levels of digital literacy can be a source of impact on both educators and students to engage with technology effectively, leading to aversion towards it (Adeba and Gatewood, 2024; Onyia et al., 2023; Temirkhanova et al., 2024). Moreover, there are different inequities with regard to the world only: as some countries are able to show high levels of GenAI adoption, institutions in Sub-Saharan Africa are confronted with infrastructural bottlenecks (poor electricity quality, expensive data plans, lower wideband adoption, et cetera), leaving learners insufficiently equipped to enter the digital economy (Almassaad et al., 2024; Maluleke, 2025; Oyelere and Aruleba, 2025). The ethical and cognitive risks, like algorithmic bias, data privacy, and over-reliance on AI by students, are poorly included in the existing models of adoption, such as the TAM and UTAUT, endangering critical thinking and autonomy (Or, 2025; Gupta et al., 2021). Lack of coordinated and data-driven conceptual framework that strikes a balance between the technological innovation and socio-educational inclusiveness has continued to propagate unfair and shallow innovation (Umoke et al., 2025). Therefore, this paper will address this gap by analysing local realities and foreign models of innovative digital learning.

Objectives of the Study

1. Examine current practices in integrating emerging learning technologies in Computer Science Education.
2. Investigate the relationship between digital literacy, institutional support, and pedagogical innovation.
3. Explore international best practices in digitally enhanced teaching and learning.
4. Develop a conceptual and data-driven model for reinventing Computer Science Education through innovation and inclusion.

Research Questions

1. What emerging learning technologies are currently being used in Computer Science Education?
2. How do educators and students perceive the usefulness and ease of use of these technologies?
3. What institutional and pedagogical factors influence their adoption?
4. What lessons can be drawn from global practices for the Nigerian and African context?

Scope of the Study

This paper focuses on the creative transformation of the field of Computer Science Education (CSE) in the digital age in terms of the integration of new technologies like AI, ML, Generative AI, LLMs, VR, AR, and MR. It is based on TAM, TPACK, and the SAMR model, and it compares the existing practise and pedagogical innovations, as well as institutional factors that may affect the adoption of technology. The investigation is reduced to higher education, and publications of 2020-2025 and examines the best practises in the world, contextualised to Nigeria and Sub-Saharan Africa. It eliminates primary and secondary education, non-English literature, direct field work, proprietary technology which is not generally available in developing situations.

Significance of the Study

The paper can contribute to bridging digital literacy gaps, technology integration, and institutional readiness gaps in the CSE, especially the underrepresented areas. It offers teachers, schools and policy makers with evidence-based thinking on how to embrace emerging and immersive technologies to improve student engagement, equity, and higher-order thinking skills. Theoretically, it builds on current adoption and pedagogical models incorporating ethical and socio-economic aspects. In practice, it suggests an inclusive

conceptual model to drive policy, decrease the digital divide, nurture innovation and entrepreneurship, as well as sustainably develop the workforce in AI-based economies.

Theoretical Framework

The theoretical approach to reinventing the learning in the digital age is built through a change of psychological models of the 20 th century into technology-driven ones of the 21th century. These theories offer the framework behind an instructional approach that will be effective and facing practical challenges that teachers and learners will encounter in a fast-changing Computer Science Education (CSE) setting (Coroiu et al., 2025).

Constructivism: Building the premise of active learning.

Constructivist Learning Theory is the main pedagogical mainstay of contemporary CSE that claims that the knowledge does not enter but is created by the learner through meaningful communication and personal experience (Umoke et al., 2025; Coroiu et al., 2025). According to this paradigm, the teacher becomes more of a facilitator rather than an informer of information and helps in just offering the conditions within which students are able to construct meaning through action (Coroiu et al., 2025). In the context of social constructivism, it is pointed out that knowledge is co-constructed in the process of interaction with peers and the environment, which is operationalized through modelling forms of instruction that mediate the gap between the abstract hypothesis and practical action (Umoke et al., 2025; Pirker et al., 2020). In addition, scaffolding also offers systematic support, enabling students to develop their competence at a speed that suits them, and then assume complete responsibility in their learning (Umoke et al., 2025).

Connectivism: Learning Network

Although traditional theories are psychology based, the theory of Connectivism is technology based and it redefines learning as the process of connecting specialised nodes or sources of information (Coroiu et al., 2025; Adeba, 2021). It recognises the internet as a huge repository of immediate information, and this moving towards a shift to the model of desktop-as-a-platform to the model of network-as-a-platform (Gupta et al., 2021). The process of teaching in this system requires the provision of the facilities and directions that the learner needs to find new directions and establish new relationships (Coroiu et al., 2025). E-learning and virtual worlds are aspects that are especially responsive to connectivism and embrace a concept based on independent and autonomous learning in a digitally oriented society (Adeba, 2021).

Technology-Based Instructional (TEL) Frameworks

Some integrated models that mediate theory and classroom practice in terms of practical innovation and adoption of technology in CSE include:

a. Technology Acceptance Model (TAM) and UTAUT: Perceived usefulness (PU) and perceived ease of use (PEOU) are key indices when it comes to the acceptance or rejection of new technologies (Davis, 1989; Or, 2025). This is expanded by the Unified Theory of Acceptance and Use of Technology (UTAUT) by involving social influence and facilitating conditions in recognising that the intention to use emergent technology such as Artificial Intelligence is highly influenced by the peer and instructor expectation (Or, 2025; Alarefi and Alharbi, 2025).

b. TPACK and SAMR Models. The Technological Pedagogical Content Knowledge (TPACK) model assumes that successful teaching should be based on the combination of knowledge of technology (TK), pedagogy (PK), and content of a subject (CK) that a teacher has (Temirkhanova et al., 2024). The level of such integration is measured with the help of SAMR Model (Substitution, Augmentation, Modification, Redefinition) that monitors the technology usage in terms of basic tool substitution to re-defining of previously impossible learning tasks (Kuhail et al., 2022).

c. Self-Determination Theory (SDT): The theory will prove beneficial in motivating the participants by addressing the psychological needs, which include autonomy, competence, and relatedness to evoke

intrinsic and extrinsic motivation in an immersive setting augmented and virtual reality (Lampropoulos et al., 2023; Or, 2025).

d. Inclusion: To promote equity, the Capability Approach concerns the personal capacity of a learner, both concretely (physically) and abstractly (cognitively), to utilise the opportunities at their disposal and practise the choice, which includes the quality of the internet and power (Maluleke, 2025; Adeba, 2021). This can be matched with the Integrated Modelling of Inclusive Educational Development (IMIED), as which associates the concept of instructional innovation directly with the concept of inclusive training and curriculum alignment in order to avoid the further expansion of the digital divide (Umoke et al., 2025).

Empirical study

Empirical studies about reinventing learning in the digital age demonstrate a complex change in various aspects of pedagogical approaches, integration of technology and socio-educational access. The existing literature prioritises institutional and regional mediators format as the shift to a network-as-a-platform model of knowledge procuring is carried out through the adoption of advanced technologies, including Artificial Intelligence (AI) and immersive technologies, but their effective implementation and success depend crucially on institutional and regional factors (Gupta et al., 2021; Onyia et al., 2023).

Empirical Research on incorporation of new learning technologies

A systematic review of the literature recently has reported an increase in the use of AI and Machine Learning (ML) in Computer Science Education (CSE). Manorat et al. (2025) reviewed 119 studies, finding out that AI and ML are actively used in the whole scope of pedagogical process, such as classroom practise, course design, and monitoring of performances. In particular, AI-powered tools, such as ChatGPT and GitHub Copilot, are fairly common in the context of the field of programming education, and they are utilised to automate such mundane aspects as grading and debugging code, enabling instructors to focus on more creative activities (Manorat et al., 2025; Wieser et al., 2023). Gaitantzi and Kazanidis (2025) conducted a subfield study on the application of AI in teaching and learning of database and discovered that interactive problem-solving and personalised learning are effective in teaching this course but continue to reveal a persistent threat of AI inaccuracy and scholarly dishonesty.

There are also a high number of empirical alternatives to immersive technologies. Kuhail et al. (2022) studied 42 papers and found out that Virtual Reality (VR) and Augmented Reality (AR) made the learning of complicated concepts easier and more enjoyable especially in STEM subjects. Likewise, an experiment by Lampropoulos et al. (2023) that involved 117 students of higher education has shown that AR together with gamification and serious games have shown great sensory experience (4.20/5.0) and positive emotional reaction that impressed students with a significant increase in learning motivation and self-efficacy.

Digital Literacy, Support, and Innovation Relationships

Digital literacy and pedagogical success are interconnected phenomena that find their reflection in the literature. A study by Temirkhanova et al. (2024) conducted in Astana International School in Kazakhstan indicated that students who received instruction on the digitally literate teachers improved dramatically in the development of virtual reality applications and mobile applications. This paper has provided an indication of the efficacy of Technological Pedagogical Content Knowledge (TPACK) model, where educators who had advanced the ability to use technological and content knowledge successfully enabled higher student achievement (Temirkhanova et al., 2024).

Organizational encouragement is a very important source of such results. Onyia et al. (2023) adopted the exploratory factor analysis technique in Nigeria and found that one among the prominent clusters that facilitate digital inclusion process is the capacity building of the institution. This is similar to the results of Adeba (2021) in Ethiopia, where inadequate management support, the ineffective infrastructure, and insufficient technical support were reported as the main barriers to the uptake of eLearning. In addition, a meta-analytic study by Or (2025) that examined 17 empirical studies concluded that perceived ease of use (PEOU) and perceived

usefulness (PU) are antecedent determinants of AI adoption with PEOU having strong impact on the attitude students have towards using these tools.

International Good Practices in Digitally Enhanced Learning.

The world trends show unequal opportunities of success depending on the local situation and policy. Students in Saudi Arabia are known to be among the world leaders in the use of generative AI; according to a study conducted by Almassaad et al. (2024) with a sample of 859 students, 78.7% of them regularly use the tools to clarify concepts and summarize the literature. On the other hand, studies conducted within the Sub-Saharan Africa underscore a stronger digital divide. Oyelere and Aruleba (2025) compared perceptions of students in Kenya, Nigeria, and South Africa and revealed that there were extensive differences in attitudes that depended on the quality of infrastructure and the attitude of the locals after AI.

The best practices in these areas note the need to encourage active learning. In a quasi-experimental study, Umoke et al. (2025) conducted among 260 students in Nigeria, using a modeling instructional strategy with a high emphasis on hands-on collaborative learning model resulted in a tremendous growth in the student interest (mean post-test score of 69.36 in comparison to 49.46 in control group) without any gender disparity. That is why it helps to give transition to student-centred methods that are close enough to the real world but at the same time are inclusive enough (Umoke et al., 2025).

The use of evidence-based theories of innovation and inclusion.

Powerful, data-driven systems are required in the re-invention of CSE. The Integrated Modelling of Inclusive Educational Development (IMIED) model suggests that it is essential to align the instructional innovation to the inclusive training and curriculum alignment in order to improve educational outcomes (Umoke et al., 2025). This monitoring, which is based on data, including Educational Data Mining (EDM), is becoming actively applied in tracking student engagement in education and finding at-risk learners in the early survey (Manorat et al., 2025; Nabil et al., 2021).

Nevertheless, such issues as ethical issues are important in such models. According to Maluleke (2025), although AI has the potential to make the administration more efficient, and pedagogy more innovative, it also poses the risk of algorithmic bias, loss of attention to privacy, and the diminishing of critical thinking. These empirical results highlight that, despite the fact that technological innovation is an effective way of reinventing learning, it can only have a sustainable effect when combined with ethically based policies and fair access to infrastructure (Maluleke, 2025; Oyelere and Aruleba, 2025).

Conceptual framework

A drastic change in Computer Science Education (CSE) pedagogy with an aim at transforming the flow of passive knowledge acquisition into a network-as-a-platform paradigm with a focus on high-level cognitive skills due to the rapid proliferation of digital technologies became inevitable (Adeba, 2021; Gupta et al., 2021). The recent innovations are oriented towards incorporating intelligent systems and depth experiences to provide student-centred and interactive learning experiences (Coroiu et al., 2025; Lampropoulos et al., 2023).

Generative AI and Large Language Renders (LLMs)

Generative Artificial Intelligence (GenAI) and the use of Large Language Models (LLMs) like ChatGPT, GitHub Copilot, and Gemini are the most prominent new development in CS pedagogy in the recent past. These systems are turning the classroom into one of an AI-native software development, with students serving as curators, who together with the AI make code, error-correct code, and systematically participate in code development (Gaitantzi and Kazanidis, 2025; Manorat et al., 2025). The adoption of these tools by students in such countries as Saudi Arabia is very high, and most of the students use it to explain difficult concepts and summarise scholarly texts (Almassaad et al., 2024; Alarefi and Alharbi, 2025). The systems are real-time and personalised tutoring that resembles one-on-one human instruction, which makes them very effective in terms of increasing the effectiveness of learning (Or, 2025; Chen et al., 2020).

Virtual Technologies and Extended Reality

Immersive computing, Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) have become increasingly important as aids to simplify concepts in abstract computing. Embodied interaction enables a student to visualise intricate structures such as algorithm execution, neural network specifications, and computer network topologies by innovations in this area (Kuhail et al., 2022; Pirker et al., 2020). As examples, VR can be used by the learners to map out the tactics of the human brain or learners can perform computer science replugged, tangible activities by mapping physical exercises into virtual environments (Kuhail et al., 2022; Pirker et al., 2020). Such technologies are especially efficient when it comes to increasing student motivation and engagement through the provision of sensory-intensive environments that 2D ones will never be able to appeal to (Lampropoulos et al., 2023; Kuhail et al., 2022).

Gamification and Serious Games

More models of pedagogy have also developed to encompass gamification and serious games that apply game features of points, leader boards, and badges out of context. These innovations evoke both intrinsic and extrinsic motivation, which creates a feeling of competence and relatedness amongst the learners (Lampropoulos et al., 2023). Collaborative learning based on mobile game-based learning applications are now available wherein students play each other in adaptive quizzes or work together to solve programming puzzles in order to enhance their computational thinking and self-efficacy (Lampropoulos et al., 2023; Manorat et al., 2025).

Automated Assessment and Learning Analytics

Assessment Testers have also innovated Intelligent Tutoring System (ITS) and automatic grading systems that offer immediate feedback and minimise the administrative workload on the instructors (Gaitantzi and Kazanidis, 2025; Onyema et al., 2021). State-of-the-art algorithms can now analyse code that is not compliable and detect commonly typed errors by grouping submitted code along functional structure (Manorat et al., 2025). Moreover,
Educational Data Mining (EDM) and Learning Analytics (LA) can enable institutions to track student performance, with clickstream logs, and interaction logs allowing institutions to monitor the progress of at-risk learners early in the semester and provide them with specific remedial instructions (Manorat et al., 2025; Or, 2025; Nabil et al., 2021).

Collaborative and Flexible Learning Platforms

In a move to adapt to the new digital age, the emergent educational models are embracing blended and online collaborative learning models. Interactive digital whiteboards (ex: MS White board) and platforms like "Change Laboratories" will allow joint planning of educators and students and stimulate an atmosphere of extensive learning (Temirkhanova et al., 2024; Coroiu et al., 2025). Also, the ease of access has been democratised by Cloud-based solution and Open Educational Resources (OER) which have ensured that learning is possible both anytime and anywhere by providing access to highly technical equipment (Onyia et al., 2023).

METHODOLOGY

The research design that was used in this study is mixed-methods, which included both quantitative and qualitative research approaches to research the adoption, pedagogical value, and institutional conditions of emerging learning technologies in Computer Science Education (CSE) in Nigeria as applied in higher education. Mixed-methods approach has been chosen as it is essential to support both quantitative aspects of technology use (quantifiable trends) and qualitative ones (in-depth information about the experience and perceptions of the participants). Evidence insights into prevalence, acceptance, and perceived effectiveness of digital tools were made through the quantitative data provided, whereas the depth of the exploration of contextual barriers, institutional realities, and improvement strategies was made possible with the help of qualitative responses. This study design is able to endorse methodological triangulation and provide greater

interpretive validity of the research findings by permitting convergence between quantitative data and narrative results.

The population of interest was Computer Science Education and other computing programmes students and lecturers in higher learning institutions in Nigeria. The higher education was selected due to its strategic contribution to the development of high levels of digital skills and training students to be involved in knowledge driven and AI-enabled economies. Purposive sampling method was selected to make sure that the subjects had the hands-on experience involving digital teaching and learning tools in the CSE settings. This method was suitable considering the expertise of the topic area and the focus of the research on knowledgeable views and not just the population estimations.

Students constituted the majority of the last sample (90.8 reticent) with a large proportion (79.5) being undergraduates which did not serve to generalise the learner centred aspect of the inquiry as well. Postgraduate students and lecturers were also surveyed enjoying the provision of instructional and institutional perspectives. Gender represented 79 percent male and 21 percent female and the institutional representation was majorly represented by state universities (94.9 percent) which provided some insight to a referenced but not always represented section of the public higher education system in Nigeria.

A structured and online questionnaire, which was developed based on the known educational technology models, such as the Technology Acceptance Model (TAM), Technological Pedagogical Content Knowledge (TPACK), and the SAMR Model was used to collect data that was conducted through Google Forms. The frameworks were used to design items of perceived usefulness, ease of use, pedagogical integration, technology transformation levels.

The questionnaire was in three sections. Section A consist of demographic and access-related variables that included gender, institutional type, academic role, device ownership, and internet connectivity. Section B was comprised of Likert-scale questions evaluating the level of integration and perceived pedagogical influence of emerging learning technologies such as artificial intelligence tools, virtual and augmented reality, gamification, collaborative tools, and learning management systems as well as institutional support and a lack of infrastructural support and constraint. The open-ended questions in section C were to enable the respondents describe their perceptions on transformative technologies, challenges of adopting transformational technologies, and measures to strengthen digital innovation in CSE.

In order to cheque the quality of the data collection tool, the questionnaire experienced expert validation by the scholars in ICT education and educational technology. This procedure was able to establish content and face validity because it ensured that there was consistency between the items of the questionnaire, the research goals and theory. The reviewers came up with several suggestions that resulted in the review being refined by amending the wording and structure of the items to make them clearer and more relevant.

Before full deployment, a pilot study was done to test internal consistency of the instrument. Cronbach alpha analysis gave a coefficient 0.72, which is good, as internal consistency, and shows that, the instrument is suitable in the conduct of educational research where the study is on perceptions and self-reported practises.

To accomplish the goal of large geographical coverage and ease participation, data has been gathered within a specific time frame via an online survey format. The online strategy was also very appropriate considering this study concentrated on the use of technology and online learning. The respondents were free to volunteer and they had been briefed on the purpose of the study before filling the questionnaire. Protections to retain anonymity and confidentiality were made and no personal information which could identify a participant was gathered. These steps were aimed at facilitating rather honest answers and minimise biasness in response.

The quantitative data were examined with the help of descriptive statistic methods, such as frequencies, percentages, mean scores, and graphical tools, to determine the trends in the technological adoption, perceived pedagogical advantages, institutional preparedness, and barriers to integration. Findings were analysed relative to the theoretical frameworks used in providing explanations to trends observed.

Thematic analysis was applied in the analysis of the qualitative data of open-ended responses. The responses were coded, categorised, and sorted into the recurrent themes representing the essential challenges, empowering factors, and the suggested strategies to enhance the digital learning innovation in CSE. The findings of the qualitative were applied to supplement and contextualise the findings of the quantitative, thus, offering deeper insight into the issues of research.

Ethical Considerations

During the study, ethical standards of research in education were strictly followed. The research was conducted via informed consent and the respondents were guaranteed of the anonymity and confidentiality of their responses. The use of data was academic and secure storage. The participants were not denied the right to pull out of study at any point without any negative repercussions.

ANALYSIS AND DISCUSSION

The demographic makeup of the respondents shows that most of the respondents are predominantly male (79%), mostly students (90.8%), with the undergraduates constituting 79.5% of the sample. The percentages of lecturers and postgraduate students are lower and this would indicate that the results are mostly based on the learners' preferences as opposed to the opinions of the educators. This population characteristic is in tandem with other studies that focus on the relevance of student voices in defining digital pedagogy (Adebayo, 2023).

Institutional representation is also significantly biassed toward the state institutions, which represent 94.9percent of the responses, and the federal and private institutions are lowly represented as well. This focal point highlights the importance of the state-level infrastructure and policy in the formation of the use of emerging technology of computer science teaching. The distribution of academic ranks also indicates that Lecturer I and lower constitute 55.6 percent of teaching staff surveyed implying that earlier-career academics have more to discuss regarding digital pedagogy. These results are consistent with the previous studies that indicated that the institutional context affects the adoption of the technologies (Okonkwo, 2022).

The data about access indicate that personal digital devices are almost unanimously owned with 98.9 percent of students and 94.4 percent of lecturers reporting access. Nevertheless, the internet access is also not uniform: although the majority of the respondents (46.8) describe their internet connexion as good or fairly connected (37.9%), a significant proportion give poor ratings. This gap indicates structural issues that do not support an equal process of technology adoption, which replicates the issues brought up in interior ICT policy assessment in Nigeria (Nwosu, 2021).

The patterns of technology adoption indicate that artificial intelligence tools and virtual/augmented reality are highly accepted with more than 90 percent of respondents agreeing or strongly agreeing that the innovations can be used in teaching and learning. Gamification and collaborative tools, in turn, have lower integration, and the statistics are 66.2% disagree about gamified platforms and 54.9% disagree about collaborative tools. It implies either minimal exposure or doubt regarding their applicability at the local level, as well as the comparative research of African digital classes (Adeyemi, 2020).

The usefulness and pedagogical impact perceptions are all positive. Respondents find that emerging tools are user-friendly (more than 90%), improve problem-solving and critical thinking (97%), and increase the interest of the lessons (97%). Notably, three quarters (89.3) feel that the rewards are much greater than the work needed to implement them. Institutional support graphs, however, are less encouraging: though 54.4% are sure that there is sufficient technical support, 24.1% say that there is a lack of this aspect of readiness. These results are consistent with the literature on the best practises worldwide that have stressed the necessity to have robust governance structures and ongoing professional growth (UNESCO, 2022).

Additional graphs on institutional policies and curriculum give positive signs, with 72.8 percent in agreement that the policies promote innovation and 65.1 percent of the respondents indicated that the curriculum would promote the use of technology. Team work and leadership are highly supported as well, although more than 90 percent concur or strongly concur that the two aspects can make the difference in the efficient use of technology. However, challenge-related charts note numerous obstacles since poor infrastructure (96.4%

agree/strongly agree) was found as the issue, high costs (89.2%), poor internet connectivity (96.5%), limited digital skills among teachers (95.9%), and resistance to change (93.8%), and time constraints (91.8%). These obstacles reflect the results of larger African educational technology research which focuses on structural and cultural obstacles of digital adoption (Ogunleye, 2021).

The survey also brings out the impact of the leadership support in spurring innovation. Having 94.4% of the people who are interviewed with the support of the idea that leadership does indeed have an impact on adoption, one can confidently state that the role of institutional leaders is critical when creating the digital learning environment. This result correlates with the literature of the world, where leadership is highlighted as an agent of educational change (Fullan, 2021).

Teamwork between lecturers and students also comes out as another important variable with 96.4 percent of the respondents agreeing or strongly agreeing that teamwork improves effective use of technology. It means that the interaction between peers and the collaboration within a team are needed to maximise the advantages of digital tools, which is why participatory models of learning are also important (Siemens, 2019).

The daunting issues of digital adoption are further highlighted by the graphs that presented the insufficient infrastructure, high cost, and poor internet connectivity as the most overwhelming issues. These results align with the wider African ICT research that implies infrastructural inadequacies as a persistent problem in the path to sustainable digital learning (Ogunleye, 2021). Digital skills are also limited among the educators as 95.9% admitted that this is a limiting factor. This indicates that there is an immediate need to have an unending professional development and training programmes to cultivate educator capacity.

Another interesting issue is resistance to change amongst stakeholders where 93.8% of respondents agreed or strongly agreed that it influences adoption. The described scenario reflects the cultural and institutional resistance that may commonly be seen in Nigerian higher education wherein existing practices and bureaucracies may slow the implementation of new teaching practices. To conquer these obstacles, the change management strategies have to be explicitly planned, and the strategy of sensitisation and awareness-raising should be implemented, aiming to make lecturers, administrators, and students accept new pedagogical practices such as CTCA and Gbeleyi 1.0 that would be relevant in the context of the global digital learning shift (Gbeleyi, 2024).

The demographic traits of the respondents reflect that a greater percentage of respondents are male (79%), and they are mostly students (90.8%), among which there are undergraduates representing almost three quarters of the sample 79.5%. Lecturers and postgraduate students have lower values pointing to the fact that the results mainly reflect the views of learners but not the opinion of educators. This population sample aligns with the research on the value of student voices on the development of digital pedagogy in Nigeria (Adebayo, 2023).

The institutional representation is highly biased towards state institutions, (94.9) percent, whereas the federal institutions and the private institutions are represented by a very low percentage. This focus indicates the severe importance of the infrastructure and policy at state levels in influencing the implementation of the emerging technologies in education in computer science. The distribution of academic rank also indicates that Lecturer I and lower constitute 55.6 percent of all teaching staff surveyed, the implication being that early-career academicians are more occupied with the discussion on digital pedagogy. These results are consistent with the previous studies that have emphasised the role of the institutional context in technology adoption (Okonkwo, 2022).

The data on access reveals Virtual universal possession of personal digital devices with 98.9% of the students and 94.4% of lecturers stating that they have access. Nonetheless, the quality of internet connexion is uneven with the largest percentage of respondents satisfied with either good (46.8%), fair (37.9%), among the majority of the respondents, whereas a significant number of people indicated poor internet connectivity. This gap indicates the presence of infrastructural issues to negatively impact equal technology uptake, which is replicated in Nigerian ICT policy literature (Onasanya and Jayeola, 2025).

The patterns of technology adoption indicate that the use of artificial intelligence tools and virtual/augmented reality has strong acceptance rates among the participants because more than 90 percent of the participants

agreed or strongly agreed that the innovations facilitate teaching and learning. Current literature testifies that the implementation of AI in the Nigerian education system leads to a higher degree of personalization and efficiency and is, therefore, a revolutionary trend in education (Bali et al., 2024; Ukala, 2024). Likewise, VR and AR as a form of immersive technology have also been found to enhance understanding and involvement in African classrooms (Wadesango, 2024). Conversely, gamification and collaborative tools are less incorporated with 66.2 and 54.9 respectively stating that they disagree about Gamified platforms and disagree about collaboration tools. This implies minimal exposure, or doubt concerning their usefulness, which is also present in Nigerian higher education in which adoption of gamification is not even (Atoyebi et al., 2025).

The usefulness and pedagogical influence are perceived mostly positively. The respondents also subscribe to the fact that new tools are user-friendly (more than 90 percent), can improve problem-solving and critical thinking (97 percent) as well as make lessons more interactive (97 percent). Notably, 89.3% consider the payoffs to be more merited as opposed to the effort needed to embrace them. The results of institutional support graphs are however inconsistent with 54.4 percent saying they have sufficient technical support and 24.1 percent saying that they do not indicating gaps in readiness. Such results can be compared with the international literature that highlights the importance of effective systems of governance and lifelong learning (UNESCO, 2022; Yusuf et al., 2024).

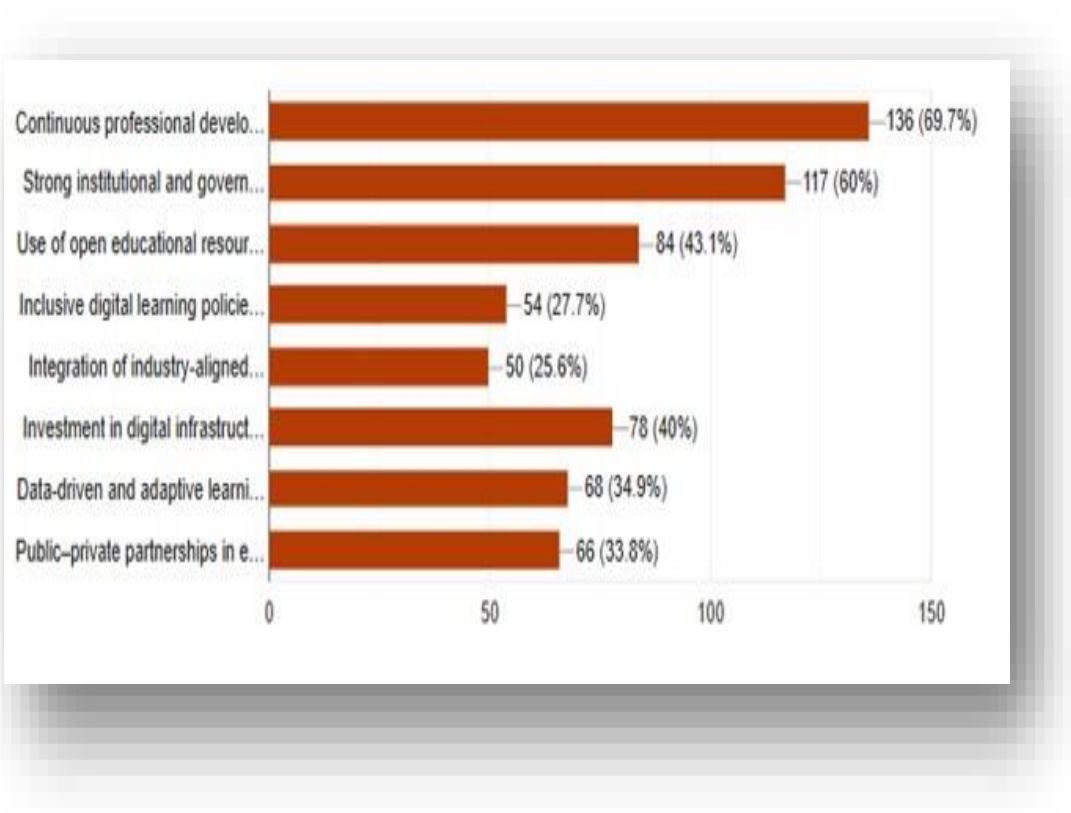

Figure 1: Adapting Global Best Practices to Nigerian Computer Science Education

Additional graphs including institutional policies and curriculum give some encouraging trends with 73.1% of them saying that the policies promote innovation and 65.1% stating that the curriculum promotes the use of technology. Teamwork and leadership are also highly rated, where more than 90 percent concur with the idea or highly agree that it contributes to effective use of technology. Still, there are persistent obstacles, which are identified in graphs related with challenges: a lack of infrastructure (96.4% agree/strongly agree), high costs (89.2%), poor internet connexions (96.5%), insufficient digital abilities among teachers (95.9%), and unwillingness to change (93.8%). These obstacles reflect the literature on African educational technology research in general, focusing on the structural and cultural barriers of digital adoption (Sarumi, 2024).

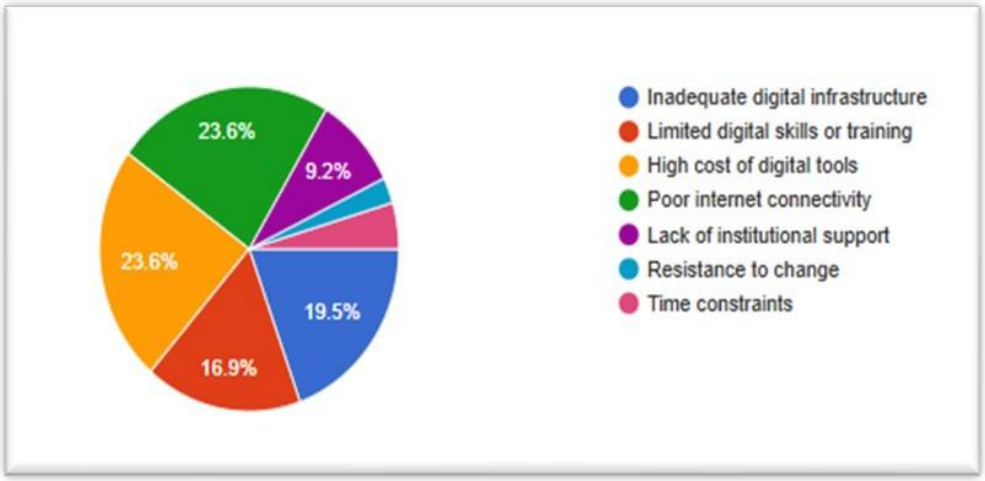

Figure 2: Survey Results on Challenges to Digital Adoption in Nigerian Higher Institutions

Last but not least, as the graphs on transformative technologies indicate, artificial intelligence tools face the greatest impact (91.3%), then online collaborative tools (63.1%), gamified platforms (46.7%), and learning management systems (46.2%). Global best practise graphs identify continuous professional development (69.7) and good governance systems (60) as the most flexible practises to be applied in Nigeria. Such insights are correlated to the international guidelines on the sustainable digital education reform (World Bank, 2023; UNICEF, 2025).

The lack of time to cover the curriculum is another factor that impedes an effective use of technology with 91.8% of the respondents agreeing and strongly agreeing. It implies that the strict forms of curriculum can deny teachers the opportunity to experiment with innovative technology, and it is necessary to reformulate the curriculum in order to focus on flexibility and digitization (Obi, 2020).

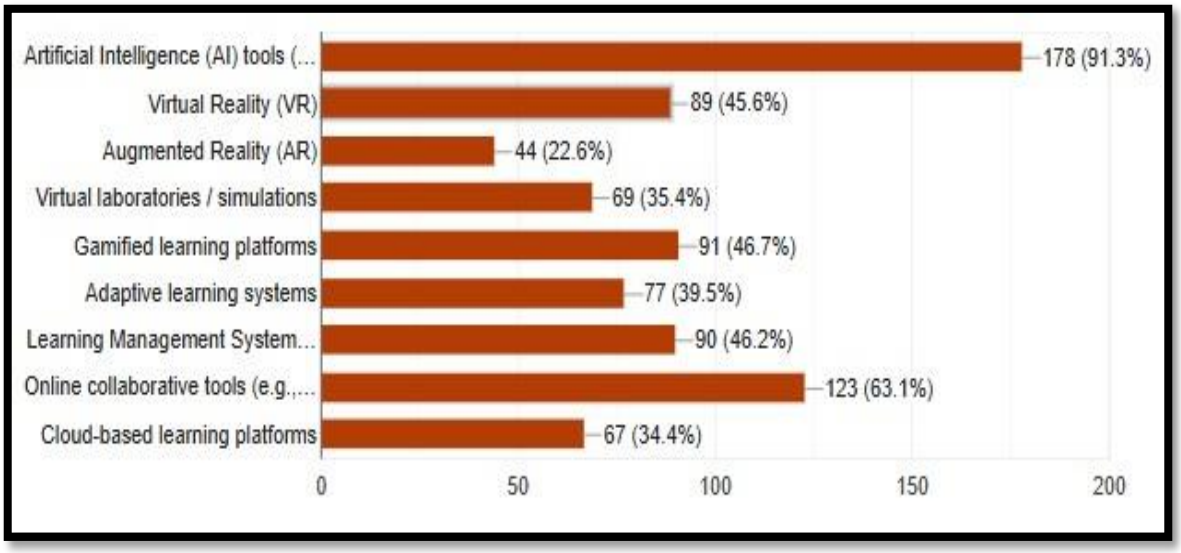

Figure 3: Adoption Rates of Emerging Learning Technologies in Nigerian Computer Science Education

Lastly, the graphs regarding transformative technologies demonstrate that artificial intelligence tools are viewed as the most significant ones (91.3%), and the next ones are online collaborative tools (63.1%), gamified platforms (46.7%), and learning management systems (46.2%). Best practice graphs on the world indicate continuous professional growth (69.7%), and robust governance structures (60) as the most versatile approaches to use in Nigeria. Such lessons are in line with the global proposals of reforming digital education sustainably (World Bank, 2023).

CONCLUSION

This paper has explored how Computer Science Education (CSE) has been re-invented during the digital era by utilising the new learning technologies with specific reference to the Nigerian higher education. The study based on traditionally recognised models such as TAM, TPACK, SAMR, and inclusive education models, merged the conceptual analysis with empirical data to examine the trends of adoption, pedagogical influence and institutional preparedness. The results reveal that digital transformation of CSE is unavoidable and essential to train learners on the high-level mental abilities and make them ready to learn in AI-driven economies.

Findings suggest that the acceptance of artificial intelligence tools and immersive technologies including virtual and augmented reality had high acceptance scores, which are broadly seen to have contributed to enhancing the activities, conceptual knowledge, and problem-solving. These results are supported by the world-wide evidence that places AI-assisted personalized information and immersive learning as one of the effective means of enhancing computational learning outcomes. Nevertheless, low relatively adoption of gamification and collaborative platforms is indicative that technology adoption is influenced not just based on perceived usefulness but contextual issues such institutional culture, educator competence, and curriculum flexibility.

Regardless of a large number of individuals having access to personal digital devices, structural barriers are still in place. The constrained internet connectivity, excessive implementation cost, -lack of digital proficiency in teachers, inflexible curriculums and resistance to change are known as significant limitations. These issues indicate that a digital divide exists, and it is putting the equity of access to the innovative learning experiences at risk. The paper also shows institutional leadership and collaboration practice to be a key driver of successful technology integration and the role of governance and organizational culture in strengthening digital education reform.

Altogether, the research has its contribution to the literature, i.e., framing global digital learning innovations in the context of the Nigerian higher educational reality. It promotes a moderate mind-set which posits technological innovation, pedagogical transformation and inclusion to be mutually protecting aspects of sustainable CSE revamping. The study presents a solid framework of possibilities to restructure the idea of Computer Science Education in the digital age by focusing on the learner-centred strategies facilitated by moral, institutional, and infrastructural alignment.

RECOMMENDATIONS

The study based on the findings suggests a strategic and system-wide view of digital transformation in Computer Science Education. To begin with, institutions need to consider ongoing professional growth of teachers and focus more on digital learning, the use of AI without violating ethical norms, and how new technologies can be applied in teaching and evaluation. Empowering the Technological Pedagogical Content Knowledge of educators is the key towards leaving superficial tools adoption in favour of the meaningful instructional innovation.

It is essential to invest in digital infrastructure on a long-term basis. Equitable technology integration relies on excellent internet connexion, low-cost access to digital tools, reliable power supply, and institutionalisation of the open education resources. These infrastructural limitations need to be considered so that, upcoming technologies do not enforce the current imbalances in education.

There should be curriculum reform in order to have the flexibility and innovation. The inclusion of emerging technologies in the traditional curricula of CSE as opposed to the common practice of offering them as an addition will aid in the advancement to the subsequent stages of pedagogical change in the terms set forth by the SAMR model. The flexibility of the curricula will also enable teachers with time and freedom necessary to use learner-centred and collaborative learning during teaching.

Leadership at institutions is supposed to create enabling systems of governance to promote innovation and also to mitigate ethical issues like privacy of data, bias in algorithms, and academic honesty. Resistance to adoption can be minimised with clear policies, coupled with inclusive change-management strategies, that can help to spread a common vision on digitally enhanced learning.

Lastly, the study needs to use longitudinal and comparative studies in future to highlight the long-term pedagogical, ethical and equity concerns of emerging learning technologies in various settings. This evidence will play a vital role in making informed sustainable, inclusive, and data-driven changes in Computer Science Education.

Ethical Consideration

Prior to commencing the study, ethical approval was obtained from Lagos State University and the participants. Written consent was secured from all participants, who voluntarily signed consent forms after being fully briefed on the objectives of the research. Confidentiality of responses was strictly maintained, and participants were assured that their involvement was entirely voluntary, with the freedom to withdraw at any stage without consequence. Throughout the research process, careful measures were taken to ensure that no participant experienced harm or exploitation, thereby upholding the highest standards of ethical responsibility.

REFERENCES

1. Adeba, M. F. (2021). Factors influencing eLearning adoption when teaching STEM disciplines in a higher education institute of a developing country
2. Adeba, M. F., & Gatewood, K. (2024). Factors influencing e-learning adoption when teaching Science, Technology, Engineering, and Mathematics (STEM) disciplines at a Science and Technology University in Ethiopia. International Journal of Contemporary Education, 7(2). https://doi.org/10.11114/ijce.v7i2.6865
3. Alarefi, M., & Alharbi, N. N. (2025). From intention to impact: Predictors and learning outcomes of AI tool adoption among Saudi university students. Journal of Information Science Theory and Practice, 13(4), 69–82. https://doi.org/10.1633/JISTaP.2025.13.4.5
4. Almassaad, A., Alajlan, H., & Alebaikan, R. (2024). Student perceptions of generative artificial intelligence: Investigating utilization, benefits, and challenges in higher education. Systems, 12(385). https://doi.org/10.3390/systems12100385
5. Chen, L., Chen, P., & Lin, Z. (2020). Artificial intelligence in education: A review. IEEE Access, 8, 75264– 75278.
6. Coroiu, A., Călin, A., Găceanu, R., & Vescan, A. (2025). Advancements, challenges, and emerging trends in computer science education: A systematic literature review of academic and professional learning. Workshop on Innovations in Computer Science Education.
7. Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly, 13(3), 319–340.
8. Gaitantzi, A., & Kazanidis, I. (2025). The role of artificial intelligence in computer science education: A systematic review with a focus on database instruction. Applied Sciences, 15(7), 3960. https://doi.org/10.3390/app15073960
9. Gbeleyi, O. A., Owoyemi, S. O., Peter, E. O., Agbanimu, D. O., Ebisin, A., & Jeremiah, A (2024) From Silence to Strength: Leveraging CTCA and Gbeleyi 1.0 to Tackle Gender Dynamics and Student Anxiety in Secondary Schools.
10. Gupta, C., Gupta, V., & Stachowiak, A. (2021). Adoption of ICT-based teaching in engineering: An extended Technology Acceptance Model perspective. IEEE Access. https://doi.org/10.1109/ACCESS.2021.3072580
11. Kuhail, M. A., ElSayary, A., Farooq, S., & Alghamdi, A. (2022). Exploring immersive learning experiences: A survey. Informatics, 9(75). https://doi.org/10.3390/informatics9040075
12. Lampropoulos, G., Keramopoulos, E., Diamantaras, K., & Evangelidis, G. (2023). Integrating augmented reality, gamification, and serious games in computer science education. Education Sciences, 13(6), 618. https://doi.org/10.3390/educsci13060618

13. Maluleke, A. F. (2025). AI adoption in African higher education: A systematic review of benefits and ethical implications. Interdisciplinary Journal of Education Research, 7(2), 1-17. https://doi.org/10.38140/ijer-2025.vol7.2.05 Manorat, P., Tuarob, S., & Pongpaichet, S. (2025). Artificial intelligence in computer programming education: A systematic literature review. Computers and Education: Artificial Intelligence, 8(100403). https://doi.org/10.1016/j.caeai.2025.100403
14. Modiba, F. S., Van den Berg, A., & Mago, S. (2025). Opportunities and challenges of generative artificial intelligence supporting research in African classrooms. South African Journal of Higher Education, 39(3), 173–193.
15. Nabil, A., Seyam, M., & Abou-Elfetouh, A. (2021). Prediction of students' academic performance based on courses' grades using deep neural networks. IEEE Access, 9, 140731–140746. https://doi.org/10.1109/ACCESS.2021.3119596
16. Nwonye, N. U., Nkan, V., & Akpan, A. E. (2025). Challenges of ICT usage among academic staff in University of Uyo, Nigeria. World Journal of Innovative Modern Technology, 9(1), 82–92.
17. Onyema, E. M., Ugorji, C. C., Nduanya, U. I., Onyewuchi, C., Ohwo, S. O., & Ikedilo, O. E. (2021). Prospects and limitations of machine learning in computer science education. Benin Journal of Educational Studies, 27(1), 48–62.
18. Onyia, U., Madueme, N., & Nwankwo, U. (2023). Drivers of digital technology adoption in engineering education. ICTIEE.
19. Or, C. (2025). Understanding factors influencing AI adoption in education: Insights from a Meta-Analytic Structural Equation Modelling study. Journal of Applied Learning & Teaching, 8(1). https://doi.org/10.37074/jalt.2025.8.1.26
20. Oyelere, S. S., & Aruleba, K. (2025). A comparative study of student perceptions on generative AI in programming education across Sub-Saharan Africa. Computers and Education Open, 8(100245). https://doi.org/10.1016/j.caeo.2025.100245
21. Pirker, J., Dengel, A. R., Holly, M., & Safikhani, S. (2020). Virtual reality in computer science education: A systematic review. VRST '20: Proceedings of the 26th ACM Symposium on Virtual Reality Software and Technology. https://doi.org/10.1145/3385956.3418947
22. Rahman, M. M., & Watanobe, Y. (2023). ChatGPT for education and research: Opportunities, threats, and strategies. Applied Sciences, 13(9), 5783. https://doi.org/10.3390/app13095783
23. Siemens, G. (2019). Connectivism: A learning theory for the digital age. International Journal of Instructional Technology and Distance Learning, 2(1), 3–10.
24. Temirkhanova, M., Abildinova, G., & Karaca, C. (2024). Enhancing digital literacy skills among teachers for effective integration of computer science and design education: A case study at Astana International School, Kazakhstan. Frontiers in Education, 9(1408512). https://doi.org/10.3389/feduc.2024.1408512
25. Umar, A., Dahiru, M., Muktar, I., Maina, U. A., Abdulkadir Abdullahi, M., & Magaji, Y. (2025). Barriers to adopting ICT-based teaching methods in Nigerian polytechnic institutions. SSRN.
26. Umoke, C. C., Ayanwale, M. A., Nwangbo, S. O., Ezeoke, N. C., Abonyi, S. O., & Olatunbosun, S. O. (2025). Modeling instructional strategies and their transformative role in enhancing engagement and equity in computer studies: A quasi-experimental study. Discover Education, 4, 215. https://doi.org/10.1007/s44217-025-00648-7
27. UNESCO. (2022). Technology in education: A tool on whose terms? Global Education Monitoring Report.
28. Wieser, M., Schöffmann, K., Stefanics, D., Bollin, A., & Pasterk, S. (2023). Investigating the role of ChatGPT in supporting text-based programming education for students and teachers. International Conference on Informatics in Schools.