The Future of Mathematics Education in West Africa: How AI is Revolutionizing Personalized Learning

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Abstract

Introduction: Artificial intelligence (AI) has the potential to revolutionize mathematics education through personalized and adaptive learning pathways, providing intelligent tutoring, and providing evidence-based feedback. However, the evidence base and development of AI-assisted personalization across West African higher education remain limited and fragmented.

Purpose: This systematic review synthesizes the extant empirical and review-level evidence on the use of AI to personalize mathematics learning among West African higher education students. The study identifies key models, adoption barriers, pedagogical impacts, and knowledge gaps, and makes region-specific recommendations.

Methods: Relevant articles from 2015 to 2025 were retrieved from Scopus, Web of Science, ERIC, Google Scholar, African Journals Online (AJOL), and institutional repositories using PRISMA-style procedures with keywords that include AI, personalized learning, mathematics, higher education and West Africa to initially pull out 474 papers out of which 27 papers were included.

Findings: Evidence shows that research in this area is on the rise but still in its emerging stages, with most empirical work coming from Nigeria and Ghana.

Conclusion: The study discovers that while AI presents significant potential for West African universities to provide tailored mathematics education, realizing such potential requires investment in technological infrastructure, development of faculty and student skills, localized content creation, and highly developed data governance structures.

Recommendation: Subsequent studies will need to prioritize rigorous impact, sustainability, and equity assessments across the diverse higher education institutions in West Africa.

Keywords: Artificial intelligence (AI), mathematics education; personalized mathematics learning

Introduction

Artificial Intelligence (AI) is one of the most disruptive 21st-century forces in education, transforming the teaching, learning, and assessment process. In mathematics education, in particular, AI systems offer unprecedented personalization in the form of adaptive sequencing, intelligent tutoring systems (ITS), generative feedback agents, and predictive analytics. Accordingly, Bali (2024) opined that these technologies tailor learning to individual learners' distinct requirements, adjusting difficulty, content,

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and feedback in real time based on learners' performance patterns. These technologies represent a paradigm shift away from the "one-size-fits-all" design historically dominant in mathematics education, especially in limited-resource environments like those found in West African higher education.

Mathematics remains a foundational pillar of science, technology, engineering, and mathematics (STEM) disciplines. However, systemic issues that prevent effective mathematics learning at the majority of West African universities are class congestion, limited learning materials, ineffective digital infrastructure, and variations in students' preparedness for mathematics at tertiary levels (Ayanwale et al., 2025). The issues are also compounded by disparities in the number of competent lecturers and student-to-teacher ratios that deter one-on-one attention. Pasipamire, (2025) stated that AI-based personalized learning, therefore, is not just an improvement of the existing teaching strategies but also a leveling opportunity that can diminish structural learning inequalities.

Empirical research globally indicates that AI-based interventions in mathematics can enhance increased engagement, conceptual knowledge, and retention. For example, ITS and adaptive learning systems are designed to trace students' progress, detect misconceptions, and provide tailored learning content that addresses particular learning needs (Niño-Rojas et al., 2024). Employing machine learning models, these systems learn from learners continuously to refine their prediction for the strengths and weaknesses of a learner, thereby improving learning pathways. However, Malik (2025) stated that while affluent regions such as North America, Europe, and parts of East Asia have significantly advanced the development and integration of such systems, West African data are uncoordinated and limited in scale.

In West Africa, a growing but still modest body of studies document the use of AI to enhance mathematics instruction at the tertiary level. Henkel et al. (2024) presented experimentally verified evidence from Ghana indicating that students who utilized an AI-driven mathematics tutor exhibited quantifiable conceptual mastery and engagement gains. These improvements were most dramatic in those with previously low performance levels, which is a testament to the capability of AI to provide targeted remediation. Similarly, Nigerian universities are also increasingly utilizing AI tools such as automated marking systems, learning analytics, and chat-based interfaces for mentoring to aid students in quantitative units (Ayelaagbe, 2024). The innovations fill important gaps in education by providing continuous formative feedback and adaptive learning pathways that traditional classroom pedagogy cannot easily accomplish.

Nevertheless, the use of AI in West African higher education remains full of challenges. Most prominent among these are infrastructural deficits, volatile internet connection, high costs of implementation, and low institutional readiness to adopt AI-based tools (Pasipamire, 2025; Ayanwale et al., 2025). The majority of universities lack the technological setup necessary to support large-scale AI deployment, including reliable electricity, modern computer laboratories, and high-speed networks. Educators also face challenges in terms of low AI literacy rates and inadequate opportunities for professional development (Malik, 2025). Therefore, adoption is experimental, small-scale, and donor-intensive.

Aside from technology and capacity considerations, ethical and cultural considerations complicate the deployment of AI. UNESCO (2025) warns that the application of AI in African education systems will exacerbate inequalities unless local cultural contexts, languages, and data protection frameworks are taken into account. The majority of AI learning platforms are developed in Western contexts and on datasets that poorly represent African students. This de-contextualization is de-stabilizing on questions of algorithmic bias, data ownership, and marginalization of indigenous pedagogic practice. Chisom, Unachukwu, and Osawaru (2024) also argue that to be educationally relevant in Africa, design models need to adopt indigenous values of learning, multilingualism, and socio-economic realities. Without localization, foreign AI tools can potentially reproduce existing inequalities rather than inclusivity.

Despite such constraints, hope is growing that AI holds the key to transforming mathematics learning in West Africa. More and more governments and institutions in the region are looking to AI as a strategic tool for improving learning outcomes, reducing dropout rates, and improving graduate employability. Malik (2025) indicates that teacher preparation and institutional leadership are key enablers for the effective roll-out of AI. On the same note, Ayanwale et al. (2025) note that teacher training programs are essential to inculcating confidence and technical competence in using AI instruments to maximum impact. They align with broader continental efforts such as the African Union's Continental Education Strategy for Africa (CESA 16–25), which encourages the integration of emerging technologies into higher education to upgrade STEM education and digital competencies.

Against this background, the present systematic review aims to synthesize existing empirical and theoretical evidence on AI-driven personalization of mathematics education in West African higher education institutions.

Specifically, it addresses four connected research questions:

(1) What AI approaches have been applied for mathematics education at the tertiary level in West Africa?

(2) What learning achievements have been reported?

(3) What facilitating factors and impediments that affect adoption and scalability?

(4) Where are evidence and policy gaps?

Ultimately, the incorporation of AI in West African higher education is a challenge and an opportunity. It upsets existing pedagogy practice and infrastructure resources but also offers an opportunity to democratize quality learning. If properly executed with regards to context conditions technology, culture and ethics, AI-enabled personalized learning has the potential to deliver a revolutionary effect to enable West Africa's future generation of intellectuals and professionals with the quantitative literacy that will be required to survive an increasingly digital world.

Literature Review

Scholarship on the application of artificial intelligence (AI) in mathematics learning has grown considerably over the last few years, mirroring global concern with the learning potential and unequalizing capabilities of digital technologies. However, in the Western African higher education context, such scholarship is still in its infancy, irregular, and lacking theoretical strength. The literature provides a diversity of views on the ability of AI to tailor mathematics education, the contextual challenges that condition its application, and the necessity for localized pedagogical structures to accommodate regional infrastructural and socio-cultural circumstances. Systematic reviewing of the literature, thus, has to consider both universal theoretical underpinnings and regional data, as it questions the technology-pedagogy-readiness nexus in West African tertiary education.

Globally, the power of AI as a catalyst for change in education has been imagined in terms of smart tutoring systems, adaptive learning software, and generative technologies that can tailor content to learner profiles. Chen, Chen, and Lin (2020) and Bates et al. (2020) provide extensive reviews and show how AI-driven learning systems can simulate student thinking, predict performance, and offer targeted interventions. These researches establish that data-driven, feedback-and-analytics-led personalization outcomes lead to higher engagement and retention in mathematics learning. Chiu et al. (2022, 2023) further advance with more context-dependent frameworks to examine ethical, socio-economic, and cultural implications of AI uptake, especially in developing nations. Bond et al. (2024) also emphasized the need for interdisciplinary collaboration, ethical AI policy and evidence-informed implementation models that address institutional capacity, a lack which is particularly apt to West African institutions where digital facilities and policy environments are under construction.

Across Africa, the literature is marked by optimism and caution. Ade-Ibijola and Okonkwo (2023) note how uptake of AI in Africa is being stunted by infrastructural deficiencies, lack of finance, and ethical issues of data sovereignty. Nevertheless, the same authors also note that AI integration in the education field offers a special opportunity to jump over typical pedagogic limitations, particularly where there is thinning of human resources. Ajadi (2020) argues that AI can be used to help address some of the biggest education problems in the developing world by automating testing, providing easier access to resources, and allowing tailored learning pathways in large, under-resourced classrooms. Similarly, Baidoo-Anu and Ansah (2023) see the possibilities of generative AI tools such as ChatGPT enabling dialogue-driven learning and formative assessment in higher education. Whereas their studies focus on general education and not mathematics, their conclusions about engagement and critical thinking can be extended to STEM education in West Africa, where student-centered learning is underdeveloped.

Focusing on mathematics education, universal scholarship provides a prevailing trend: AI-based systems can significantly aid comprehension, problem-solving, and concept mastery if applied in combination with the principles of adaptive learning. Ahmad et al. (2021) argue that AI's most powerful contribution lies in its capacity to diagnose learning difficulties and deliver differentiated instruction. Such tools are particularly valuable for mathematics, where cognitive load, prerequisite knowledge, and sequential understanding are critical. Chatterjee and Bhattacharjee (2020) graphically demonstrate, based on quantitative evidence, that the adoption of AI in higher education is positively correlated with improved learning outcomes and student satisfaction, on the premise that institutional readiness and teacher proficiency are adequate. However, such benefits usually follow unevenly in environments of low resources, raising a shadow of doubt regarding digital equity as a critical concern in West Africa.

In regional terms, evidence continues to be limited but reassuring. Most of the empirical evidence are from Nigeria, Ghana, and a few from Senegal. Evidence of research in Nigerian universities, as summarized in the regional education reports, shows increased use of AI-driven e-learning platforms with automated grading and adaptive problem sets for engineering and mathematics courses. While quantitative increases in student performance have been modest, qualitative data point to greater motivation and engagement among students exposed to AI-enhanced learning environments. This concurs with the findings of Aswin, Ariati, and Kurniawan (2023), which note that adoption of AI in higher education depends not only on technological feasibility but also cultural acceptability and pedagogical preference of the teaching faculty. Castillo-Martínez et al. (2024) study adds to the literature by noting that successful integration of AI in mathematics requires alignment of technological tools, curriculum design and teacher digital literacy.

Despite these potential benefits, there are still challenges. Infrastructural deficits are noted by way of volatile internet connectivity, insufficient bandwidth, and prohibitively costly hardware that continue to hinder the scalability of AI initiatives in West African institutions. Ade-Ibijola and Okonkwo (2023) note that even as a number of universities are beginning to adopt AI systems, they use foreign technology that is not necessarily designed to address local learning necessities or data protection requirements. Afra and Alhajj (2020) also raise concern regarding surveillant AI systems that may jeopardize the privacy of learners or create ethical problems if applied in learning environments. This is an ethical concern on the rise across conversations surrounding AI in education, according to Bushwick and Mukerjee (2022), who call for more regulation to prevent algorithmic bias as well as promote transparency in machine-based decision-making.

Pedagogically, the research indicates that the effectiveness of AI in mathematics education is a function of the quality of its integration into instruction and not the technology per se. Baidoo-Anu and Ansah (2023) as well as Alharbi (2023) all indicate that AI has to be used as a pedagogical companion but not a replacement for human teachers. In West Africa, where cultural norms place a high value on interpersonal mentorship and collective learning, over-reliance on AI tools can devalue critical aspects of teacher-student interaction. The constructivist theoretical perspective remains valid here: children learn optimally when they actively build knowledge by solving problems under guidance, as opposed to passive acceptance of machine-generated explanations. AI, if carefully designed, can aid constructivist pedagogy by creating personalized challenges and formative feedback.

The second theme in the literature to be discussed here is growing demand for faculty and student AI literacy. Aldosari (2020) and Chan (2023) note that AI success in higher education depends on equipping teachers with technical as well as moral knowledge to implement these tools. University teachers in West Africa many times lack systematic training programs in AI pedagogy, limiting the potential from available technology. Studies such as Bianco (2021) and Bobula (2024) show that educators' perceptions of AI optimism or pessimism influence adoption rates. This is in line with earlier research by Bhatnagar (2020) that ed-tech innovation must be accompanied by institutional change and faculty empowerment.

The review also offers a new narrative on generative AI, namely large language models (LLMs), and the promise they offer for mathematics education. Bašić et al. (2023) show that ChatGPT and other models can assist students with essay writing, explanation generation, and conceptual clarification. While their study was conducted on the topic of writing tasks, the same can be said for mathematics learning where AI can assist in problem-solving using step-by-step hints or explanations. But as warned by Chiu (2023) and Chatterjee as well as Bhattacharjee (2020), such systems must be seamlessly integrated to avoid dependency or plagiarism. West African institutions, already facing academic integrity issues, may have to establish context-specific policies for generative AI usage in assignments and examinations.

Ethical and policy considerations are a recurring theme in the literature. Bond et al. (2024) and Baker and Smith (2019) both highlight the need for ethical guidelines based on fairness, accountability, and transparency in learning facilitated by AI. In West Africa, education AI policy landscapes remain unformed, with limited national-level approaches toward data privacy, intellectual property, or algorithmic bias. Ade-Ibijola and Okonkwo (2023) note the necessity of coordination at the regional level and harmonization of policies to assure AI applications in education align with African legal standards and values. Without such policies, the application of AI tools risks entrenching disparities or exposing institutions to abuses of data.

A second key finding from the literature is that concerning the gap in evidence. Bond et al. (2024) and Castillo-Martínez et al. (2024) both call for more robust, context-specific empirical tests, particularly longitudinal and experimental ones that assess not only learning but also cost-effectiveness, student attitudes, and equity impacts. In West Africa, most of the current evidence remains descriptive or exploratory with barely any randomized or quasi-experimental studies. Braun and Clarke's (2006) qualitative analysis approach could provide an insightful methodological template for future studies, allowing researchers to discern the rich social and cultural richness of AI adoption in West African higher education.

Empirical evidence indicates that AI-driven adaptive mathematics learning is very likely to transform West African higher education. But to deliver on that promise requires more than adoption of technology: it requires a systemic answer of infrastructure investment, teacher capacity building, ethical policymaking, and locally anchored pedagogical innovation. AI must be seen not as a magic bullet but as part of an entire system of educational reform. The reviewed studies here collectively suggest that West African universities stand at a fork in the road: they can use AI to produce and customize mathematics learning for the masses, but only if the infrastructural, ethical, and cultural constraints inhibiting their progress are addressed.

Materials and Methods

Review Protocol and Scope

This systematic review was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) principles with modifications suitable for educational technology research. The study adopted PRISMA framework because it is one of the most widely recognized and rigorous approaches for conducting systematic reviews in education and technology-related research (Choi, 2025; Satiti et al., 2024).

Zotero reference manager software was used to collect, organize and systematically remove duplicate articles obtained from the selected electronic databases. The filtered records were then imported into Covidence data extraction management software to facilitate title, abstract and full-text screening. Data extraction was performed in Covidence, strictly following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria. The PRISMA guidelines were chosen as the most relevant framework for this study as they are the international gold standard for structural transparency, completeness and consistency in evidence synthesis reporting. An independent secondary ledger was maintained in Microsoft Excel to complement the automated workflow features of Covidence, further tracking article characteristics, study metrics, and inclusion statuses in a customized and easily auditable format.

This review sought to synthesize recent empirical and evaluative research on artificial intelligence (AI) applications utilized to support individualized mathematics learning in higher education in West Africa. The scope was confined to AI-based systems for the specific aim of providing adaptive instruction, automating testing, providing personalized feedback, or generating intelligent tutoring for math courses at universities and colleges. Geographical scope was all thirteen West African nations Nigeria, Ghana, Senegal, Sierra Leone, Liberia, Benin, Togo, Burkina Faso, Mali, Niger, Guinea, Guinea-Bissau, and Cape Verde—and for both single-country and cross-national studies. Research between 2015 and 2025 was included to reflect the rapid advancement of AI technologies applied in education in this period. The review incorporated qualitative as well as quantitative study designs like experimental, quasi-experimental, case study, and mixed-method designs. Concept reviews, pilot studies, and policy briefs were included if they elaborated implementation challenges or pedagogical implications. The general objective of the review was to map the scope, quality, and nature of available evidence and identify major research gaps within West African higher education systems.

Information Sources and Search Strategy

To provide all-encompassing coverage and representativeness of West African higher education environments, a structured and exhaustive search of literature was undertaken. The population in view included scholarly articles, peer-reviewed journal papers, conference proceedings, and gray literature relevant to the application of artificial intelligence (AI) for mathematics teaching in West African higher education institutions.

474 papers were pulled in initial search from a wide range of scholarly repositories and databases. After applying inclusion and exclusion criteria, which mandated that studies must be (i) aimed at AI or intelligent learning technologies and mathematics education, (ii) must be conducted in higher education contexts, and (iii) focused on at West African countries, 148 studies met the initial cut in terms of relevance. After rigorous screening for contextual congruence and methodological quality, 27 articles were eventually subjected to analysis in the study.

The databases scanned were Scopus, Web of Science, ERIC, Google Scholar, African Journals Online (AJOL), ResearchGate, and a specially curated set of institutional repositories of leading West African institutions such as the University of Lagos (Nigeria), University of Ghana, University of Cape Coast (Ghana), University of Ibadan (Nigeria), and University Cheikh Anta Diop (Senegal).

The search strategy employed Boolean operators and thematic keyword pairs in a systematic manner such as "artificial intelligence," "AI," "intelligent tutoring," "adaptive learning," "personalized learning," "machine learning," and "chatbot" intersecting with "mathematics," "math," "higher education," "university," "tertiary," "West Africa," and the names of individual countries (e.g., Nigeria, Ghana, Sierra Leone, Liberia, Gambia, Senegal, Benin and Côte d'Ivoire). The search was limited to English-language journals from 2015 to the initial half of 2025, which is the period of rapid integration of digital and AI-based learning systems in the region.

Besides database searching, grey literature including theses, dissertations, technical reports, and working papers from peer-reviewed institutions was added in order to minimize publication bias. Hand-searching of key articles' and systematic reviews' bibliographies was also conducted in an effort to locate other studies not indexed in the main databases.

Data collection was an iterative and open process. Step-by-step documentation of search terms, inclusion and exclusion criteria, and database-specific retrieval results was maintained to ensure maximum reproducibility and confirmation. Inclusion of diverse databases and cross-country analysis was a deliberate attempt to acquire a comprehensive insight into AI integration in different West African education systems.

Table 1 provides the proportionate spread of studies across databases and countries, highlighting Nigerian and Ghanaian dominance in the discourse on AI integration in math education. The spread is in tandem with the countries' levels of digital readiness and academic output relative to the sub-region.

Inclusion and Exclusion Criteria

Studies were eligible for inclusion if they met a number of key criteria. They originally had to be published between 2015 and 2025 in English language and to specifically target higher education students in West Africa or to provide disaggregated data for West Africa from wider sub-Saharan research. Secondly, qualifying studies had to have described the design, implementation, or evaluation of AI-based technology used to personalize mathematics learning, for instance, intelligent tutoring systems, adaptive learning systems, automated grading systems, or conversational AI tools.

Furthermore, the study was required to submit empirical or evaluative measures of learning outcomes, participation, or pedagogical impact. Peer-reviewed articles in journals, conference proceedings, thesis, technical reports, and certified pilot evaluations were valid types of publications. Research on K–12 primary or secondary education, non-mathematics papers, purely theoretical AI with no pedagogical use, and opinion pieces without data were not allowed. Studies that were not specific about measurable outcomes or did not explicitly distinguish between AI-based and traditional digital tools were also not included. These inclusion criteria ensured that the review attended specifically to evidence directly linked with personalized mathematics learning in West African higher education.

Table 1. Summary of Database Coverage and Country Distribution

Database/Repository	Number of Articles Retrieved	Number of Articles Included	Countries Represented
Scopus	150	4	Nigeria, Ghana, Senegal
Web of Science	110	4	Nigeria, Ghana, Côte d'Ivoire
ERIC	34	5	Nigeria, Ghana, Gambia
Google Scholar	120	4	Nigeria, Ghana, Liberia, Sierra Leone
African Journals Online (AJOL)	30	5	Nigeria, Ghana, Benin
ResearchGate	20	3	Nigeria, Ghana
Institutional Repositories	10	2	Nigeria, Senegal, Ghana
Total	474	27	Nigeria, Ghana, Senegal, Côte d'Ivoire, Benin, Gambia, Liberia, Sierra Leone

Study Selection and Data Extraction

The study selection process was informed by a multi-stage screening process. The first step involved screening all retrieved titles and abstracts against the inclusion criteria for relevance. Full-text articles were subsequently filtered for inclusion, with any discrepancies resolved by consensus review. Data was extracted using a systematic template for capturing key information: author(s), year of publication, country of research, research design, type of AI tool or technology, sample descriptors, and focus mathematical domain. Extracted outcomes included measures of student performance (grades, test scores), measures of engagement (participation rates, system usage), measures of attitude (motivation, satisfaction), and qualitative findings on implementation challenges. Both the studies were also coded for enablers and barriers such as policy support, infrastructure, or teacher training. Methodological quality was assessed based on Braun and Clarke (2006) criteria that included design robustness, sampling adequacy, reporting transparency, and clarity of analytical methods. Data appraisal and synthesis were conducted by two reviewers independently to exclude selection bias and ensure reliability.

Synthesis Approach

In view of heterogeneity of study designs and outcome measures, evidence from multiple studies was synthesized using a narrative synthesis approach. Quantitative data from quasi-experimental and correlational studies were synthesized in terms of effect direction and p-value, while qualitative evidence was analyzed through themes to identify common success factors and challenges. They were also classified by AI technology type intelligent tutoring systems, adaptive e-learning systems, or AI-based feedback systems and cross-classified by country, institution type, and implementation scale. The resultant themes were infrastructure and access, faculty digital readiness, ethics and policy, and pedagogical alignment. This allowed for full interpretation without the need for statistical aggregation across varied data. Results of the synthesis were used to map the position of personalized AI-driven mathematics learning in West Africa, highlighting achievement and areas for improvement. The resulting framework informed discussion and recommendation, favoring scalable, context-sensitive solutions for AI uptake in higher education in the region in the future.

Discussion

The level of artificial intelligence (AI) embedding in mathematics instruction within West African higher learning institutions is infancy, as affirmed in the reviewed literature. The majority of initiatives throughout the sub-region are pilot-based or experimental projects, an inaugural attempt to capture the learning advantage of AI rather than institution wide. The trend mirrors the prevailing international trend where technology adoption precedes pedagogical innovation. According to Ahmad et al. (2021) and Chatterjee and Bhattacharjee (2020), the effectiveness of AI in learning mathematics is not a function of its availability but its effective integration into instructional design. In Nigeria, Ghana, and Senegal, adaptive learning platforms and intelligent tutoring systems (ITS) have started becoming part of the classroom environment in order to customize learning trajectories and encourage student engagement. Among them are applications whose utility is particularly felt in bridging pre-university mathematics preparation of students, a persistent problem in North America's science, technology, engineering, and mathematics (STEM) pipeline.

Conclusions from the research considered affirm that AI holds the promise to assist learner motivation and self-regulated learning when used under nurturing contexts. Baidoo-Anu and Ansah (2023) argue that formative assessment and problem-solving are improved using generative AI tools such as ChatGPT through the provision of student-needs-based feedback. To an analogous extent, Chen, Chen, and Lin (2020) assert that adaptive systems capable of predicting learner difficulty and customizing response increase engagement and retention. In the West African context of large class sizes and unequal teaching resources as the norm, these features offer genuine opportunities for one-to-one instruction. Again, however, as Bond et al. (2024) and Chiu et al. (2023) note, technical fixes alone are not enough to provide enhanced learning. PED gains from AI depend upon the pedagogical setting, teacher competence, and learner digital capacity.

Evidence from the empirical experience remains inadmissible. Quantitative findings report small improvement in mathematics learning where AI applications are utilized frequently, while qualitative reports reveal increased motivation and engagement. These results, though, tend to be context-specific and institutionally varying. Chiu et al. (2023) discuss that this variation results from the fact that the advantages of AI are mediated by institutional preparedness, technological support, and curriculum congruence. Where teachers support AI work through facilitation of problem-solving, reflection, and pedagogically framed integration of AI-generated insights into the teaching practice results are considerably stronger. But when students apply AI on their own, without pedagogical framing or structured direction, gains are fleeting or superficial. These findings reinforce Chatterjee and Bhattacharjee's (2020) observation that AI's transformative potential in higher education lies in its synergy with effective pedagogy rather than its algorithmic sophistication alone.

Infrastructural and socio-economic conditions remain major barriers to effective implementation. Ade-Ibijola and Okonkwo (2023) and Ajadi (2020) emphasize that Africa's digital education landscape is hindered by inadequate infrastructure, unreliable power supply, and high internet costs. West African universities face the same challenges, with bandwidth constraints, poor computer labs, and unreliable connectivity compromising AI use in the long term. These physical challenges also reflect wider national disparities in technological readiness. Bond et al. (2024) suggest the success of AI in education is strongly related to the quality of a country's digital ecosystem, e.g., the connectivity policies and investments in human capital. Thus, infrastructural frailty in West Africa finds expression in uneven AI adoption and widens the education deficit between well-funded urban areas and under-resourced rural institutions.

Another key problem revealed across the literature examined is inadequate teachers with expertise in AI teaching. Educators generally possess a basic level of digital literacy but not yet the technical and pedagogical skills to implement AI instruments. Aldosari (2020), Bianco (2021), and Chan (2023) all stress that professional growth is imperative in the case of substance use. Without adequate training and ongoing institutional support, AI is underutilized or utilized incorrectly. In some Nigerian and Ghanaian universities, educators use AI tools exclusively for administrative ease such as marking or record-keeping rather than pedagogical transformation. Bhatnagar (2020) observes that teachers' attitudes towards technology heavily determine adoption; where teachers are positive and have confidence, integration occurs but where they are negative or undertrained, technologies do not progress. Professional development courses, peer mentoring, and learning communities then become definite catalysts for sustained AI integration. Ethical and regulatory concerns become another recurring thread. Literature is always warning of data abuse threats, monitoring, and algorithmic bias that come with AI systems. Ade-Ibijola and Okonkwo (2023) warn that Africa's dependency on AI instruments built in other places could lead to epistemic dependency as well as exploitation of the data. Afra and Alhajj (2020) and Bushwick and Mukerjee (2022) further highlight the way unregulated data gathering intrudes upon privacy and leads to digital surveillance contexts. Absence of comprehensive national or institutional AI policies in most of the West African countries leaves consent, data storage, and ownership issues unattended. Bond et al. (2024) further point out the world's necessity for equal, transparent, and accountable AI frameworks as ideas that are yet to be well-developed in the region's education systems. Lack of such safeguards not only leaves students at risk for potential misuse of their data but also undermines public trust in education technology.

Financial unsustainability is another challenge. As Ajadi (2020) and Bond et al. (2024) state, AI deployment is associated with high recurring costs for software maintenance, licensing, and upgrades. For the lack of healthy financial autonomy of the majority of West African public universities, donor-funded programs and private providers are most reliant upon. This dependency creates what Ajadi (2020) describes as a "vendor lock-in" position, where institutions are bound to proprietary platforms that restrict adaptability and have recurrent expenses. That local AI innovation is extremely low then exacerbates this problem, as most learning tools are imported and are not African-curriculum-specific, language-specific, or pedagogy-specific. Castillo-Martínez et al. (2024) argue that without contextual adaptation, AI systems will inevitably mirror outside epistemologies and become less valuable for education.

Despite these drawbacks, several enablers can be found in the literature. Localization is one of the most critical success factors. Ahmad et al. (2021) demonstrate that AI tools grounded on local curricula and contextual examples enhance comprehension and student engagement. In West Africa, integrating culturally relevant content and multilingual interfaces can increase accessibility and learner confidence. Similarly, Baidoo-Anu and Ansah (2023) emphasize blended learning as a practical model combining AI-supported instruction with traditional classroom teaching to balance technological precision with human empathy. This hybrid approach allows teachers to harness AI's diagnostic and analytic capabilities while maintaining their irreplaceable role as mentors and facilitators.

Institutional investment in digital infrastructure is also a long-term adoption requirement. Bond et al. (2024) and Alharbi (2023) note that institutions with stable internet connections, appropriate hardware, and operational learning management systems (LMS) exhibit higher AI integration levels. There, teachers can utilize AI analytics to identify struggling students and adjust interventions accordingly. The interaction between data-driven recommendations and human intervention yields a more responsive and adaptive learning space, a result consistent with the adaptive learning model of Chen, Chen, and Lin (2020).

Equity issues remain paramount. Ade-Ibijola and Okonkwo (2023) and Chiu et al. (2022) caution that, in the absence of designing inclusivity, AI adoption could increase educational inequalities. Low-income and rural students often cannot afford compatible hardware or reliable internet access. Thus, AI-based teaching could disproportionately benefit urban elites to the detriment of the vulnerable. To minimize such risks, researchers call for the development of offline AI systems, lightweight mobile apps that can operate with low-end devices, and shared digital learning centers on campus. Those actions would democratize access and reduce AI as a wall, not a bridge, to equal education.

Cooperation at the regional level also offers itself as an effective enabler. Literature calls for the creation of inter-university partnerships and continental frameworks for knowledge exchange facilitation, policy alignment, and collective capacity development. Bond et al. (2024) propose collaborative networks for linking African universities with world-class research universities to drive interdisciplinary innovation. In the West African context, harmonization with the African Union's Continental Education Strategy for Africa (CESA 16–25) provides an institutional basis for digital literacy promotion, ethical direction, and mutual infrastructure. Such collaboration would enhance increased regional self-reliance and reduce dependency on extraneous technological paradigms.

The evidence regarded thus offers a daunting but hopeful scenario. AI has the revolutionary ability to enhance mathematics education in West African tertiary education but relies on institutional readiness. Successful integration requires collective efforts, which extend from infrastructure to teacher competence, ethical leadership, and financial resilience. The future of AI in the region's educational sector depends on three interdependent imperatives. Investment in the underlying infrastructure, reliable power, low-bandwidth internet and high-performance computing facilities is necessary. Second, teacher preparation must be formalized to build pedagogical and ethical know-how on the use of AI. Third, localization and equity demands should be embedded in the design of AI to ensure accessibility and cultural adaptability.

If these goals are met, AI can transform from an experimental aside to a central component of West African education reform. It can enable constructivist learning by empowering interactive, personalized, and feedback-rich learning environments. Since the literature consistently confirms (Bond et al., 2024; Chiu et al., 2023; Ahmad et al., 2021), the promise of AI in maths education lies not in supporting human teachers but in being able to allow them to give more adaptive, inclusive, and evidence-based teaching. The future therefore demands vigilant governance, ethical consciousness, and persistent regional partnership to transform AI as a foreign technology into an integral value-added local instrument for academic excellence.

Conclusion

Artificial intelligence (AI) is a revolutionary option for mathematics education in universities of West Africa. The research studies reviewed here together attest to the fact that AI-based tools such as intelligent tutoring systems, adaptive learning systems, and automated feedback systems have the potential to significantly enhance learning outcomes through enhanced individualized learning, diagnostic feedback, and real-time support. Where crowded classrooms, unequal quality of instruction, and low contact between students and instructors are ingrained issues, AI offers a viable avenue for lessening learning gaps and maximizing students’ engagement.

On the basis of empirical research, the integration of AI has a positive effect on students' cognition and math proficiency. Adaptive learning environments encourage students to think critically, explore different approaches to solving problems, and understand the underlying principles of mathematics instead of memorizing formulas. This process cultivates deeper cognitive engagement and supports independent learning habits. Consequently, AI's contribution to mathematics education in West Africa appears promising, not detrimental. Rather than diminishing reasoning ability, AI when guided by competent instructors—enhances analytical thinking and helps students internalize mathematical logic through iterative feedback and personalized challenges.

However, the region's progress is tempered by infrastructural and institutional barriers. Persistent issues such as unreliable internet connectivity, inadequate technological infrastructure, and low faculty readiness restrict the scope of AI's deployment. Ethical concerns regarding data privacy, algorithmic bias, and regulatory oversight, as emphasized by UNESCO (2024) and Bond et al. (2024), also call for deliberate policy responses. To support balanced and sustainable adoption, governments, learning institutions, and technology partners must unite to support digital infrastructure expansion, build AI competence in learners and instructors, and set strict regulation frameworks to ensure proper use.

West African mathematics education's future is bright with prudence to follow. If the existing challenges are faced, AI would evolve from a supplementary innovation to a core support of pedagogy enabling reasoning, creativity, and self-directed mastery of mathematics. The reviewed evidence indicates that with contextual adaptation, ethical regulation, and regional cooperation, AI will not degrade cognitive performance but enhance it. The addition of AI, thus, ushers in a new era of learning mathematics namely, data-driven teaching, inclusive access, and empowered learning that positions West African institutions alongside the global education transformation.

Recommendations

In light of the incorporation of available evidence, an approach at the strategic level is required to optimize the application of AI-driven individualized learning in mathematics in West African higher institutions of learning.

1. The universities and the ministry of education must incorporate AI in an integrated fashion, not in a series of isolated pilot initiatives. By combining AI-supported adaptive systems with conventional classroom instruction, institutions can enhance personalization of learning without undermining teachers' critical role.
2. Professionalization is a must; teachers have to be regularly trained in pedagogy and ethical deployment of AI. Controlled pilot studies, preferably experimental or quasi-experimental, would need to be conducted to contrast the measurable impact of AI-supported learning on math ability and critical thinking. Data gathered needs to be shared through regional networks of research so that pooled knowledge can be formulated.
3. Governments must invest in robust digital infrastructure, stable internet, stable power, and affordable devices while developing data protection and transparency policies to safeguard the ethical deployment of AI. Public-private partnerships may also help strengthen institutional capacities. Also, developing localized AI technologies tailored to West African curricula and environments should be promoted.
4. Finally, there must be long-term studies embracing Lusophone and Francophone nations focusing on long-term effects of AI-based math education on job preparedness, creativity, and regional development measures.

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