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Artificial Intelligence-Powered Adaptive Learning Platforms As A Tool For Numeracy Intervention Among At-Risk Early Learners In Nigeria's Basic Education System

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Abstract

Numeracy difficulties among young learners are still one of the main persistent issues faced by Nigeria's basic education system, with a high number of pupils in public primary schools unable to perform basic arithmetic exercises. Already vulnerable young learners, particularly those in poor-resourced, rural, and communities faced with conflicts, are severely affected due to large class sizes, teacher shortages of teachers and the lack of individualized instructional support. Conventional, one-size-fits-all numeracy instruction has proven insufficient in tackling the heterogeneous learning demands of these children, as it is largely uniform in pace and content and incapable of responding to individual misconceptions in real time. This study proposes and evaluates an AI-powered adaptive learning platform that integrates learner profiling, diagnostic assessment, and machine learning-driven content sequencing to deliver individualized numeracy intervention for at-risk early learners. Adopting experimental research design, the study collected and analysed structured learner interaction data from a stratified sample of at-risk early learners drawn from rural and urban school contexts, comparing outcomes with a non-adaptive control group. The platform adopts classroom developed diagnostic findings, response-time logs, and error-pattern analysis to continuously calibrate task difficulty and provide arrangements, real-time feedback to learners. Adaptive algorithms, including rule-augmented machine learning models and mastery-based sequencing techniques, were put in place and assessed using indicators such as numeracy mastery gain, rate of engagement, error-reduction rate, and time-to-mastery. The study is guided by five research questions and corresponding hypotheses. The data shows that AI-powered adaptive platforms notably do better than static, non-adaptive numeracy instruction in accelerating mastery among vulnerable pupils while

maintaining greater engagement and less frustration-related disengagement, and that the study generalise across rural, semi-urban, and urban learner groups. All null hypotheses of no difference were rejected. The developed foundation roots adaptive learning in a continuous intervention cycle which includes diagnosis, personalisation, feedback, and progress monitoring. This research concludes that AI-powered adaptive learning offers a quantifiable and context-sensitive remedy for reinforcing foundational numeracy end result, lowering learning poverty, and supporting equitable basic education delivery in Nigeria, and recommends its integration into current national learning-recovery programmes.

Keywords: Artificial Intelligence, Adaptive Learning, Numeracy Intervention, At-Risk Learners, Basic Education

INTRODUCTION

Background of Study

Foundational numeracy is widely identified as one of the major factors in determining the future of children's academic achievement, economic output, and social mobility. Despite this, a significant number of young learners across sub-Saharan Africa keep leaving the lower basic education level without the ability to solve basic arithmetic operations expected at their grade (Nwoke et al., 2024). Both national and international learning assessments in Nigeria have consistently demonstrated that most pupils in public primary schools are unable to correctly perform grade-level numeracy exercises. This is a phenomenon frequently described in the literature as ‘‘learning poverty’’ (Umali, 2024). This crisis is most common among vulnerable learners, including children in rural, conflict-affected, and low-income urban communities, who often contend with highly populated classrooms, poorly trained teachers, and lack of access to individualized instructional support (Napoleon et al., 2026).

A major challenge associated with numeracy instruction in Nigeria’s basic education system lies in the improper use of uniform, whole-class teaching techniques and the highly heterogeneous learning needs of pupils within a single classroom (Musa, 2025). Balogun et al. (2026), assert that teachers in poorly resourced schools are usually unable to notice and respond to individual learners' specific numeracy misconceptions in real time, with sizes of class that are often more acceptable pupil-teacher ratios. As a result, at-risk learners who fall behind early are rarely given the appropriate solution required to bridge emerging differences, and these gaps compound over subsequent academic years (Napoleon et al., 2026). Traditional remedial approaches, which rely on generic worksheets and fixed-pace instructional materials, have proven insufficient in addressing the dynamic and individualized nature of numeracy misconceptions, as they are largely reactive and incapable of adjusting to a learner's evolving skill profile (Balogun et al., 2026; Enehezei et al., 2026; Musa, 2025).

The constraints of traditional remedial instruction have created the need to adopt intelligent and adaptive measures that can tackle the complexity and diversity of early numeracy development. Artificial Intelligence, particularly machine learning-based adaptive learning systems, provides promising remedy by supporting platforms to model an individual learner's mastery state and automatically adjust the difficulty of task, pattern, and feedback to fit that learner's demands (Gligorea et al., 2023). AI-powered measures can be sensitive to a learner's error patterns, pacing, and engagement signals, recognise specific misconceptions, and provide targeted micro-interventions in real time unlike static instructional materials.

Some recent developments in AI-based educational technology have proved the impact of adaptive learning methods in boosting foundational literacy and numeracy outcomes across different settings (Okoi et al., 2026). These platforms assess substantial numbers of learner interaction data to differentiate between

foundational errors, procedural slips, and pacing difficulties. This supports proactive and individualized numeracy intervention (Apata et al., 2025). Based on an investigation by Akinrotimi et al. (2025), early and regular recognitions of repeated error sequence support timely scaffolding and remediation before misconceptions become entrenched, especially among learners already noted as academically vulnerable.

Additionally, the growing policy placed great emphasis on foundational learning recovery in Nigeria's basic education reform highlights the urgency of growing robust, scalable, and technological interventions that are based on context (Balogun et al., 2026). Lasting low numeracy reach among vulnerable learners can result in severe long-term consequences like early school dropout, reduced self-efficacy, and lowered future economic involvement (Opesemowo et al., 2025). Across the world, experience with AI-supported education additionally recommends that, early introduction of such systems into a learner's academic trajectory will improve their protective effect against irreversible learning loss, strengthening the case for early-grade intervention rather than remediation at later, more costly stages of basic education.

To add to the academic consequences of numeracy differences that are unsolved, the psychosocial aspect of learning poverty needs proper attention. Vulnerable learners who keep experiencing failure in numeracy exercises under uniform, non-adaptive instruction often build reduced confidence and growing disengagement from activities that are related to mathematics, a sequence that tends to prevail in the next grades and, in severe situations, into adulthood (Opesemowo et al., 2025). Conversely, adaptive learning systems are developed to manage task difficulty to a learner's current mastery level, thereby reducing the frequency of avoidable failure experiences and creating a more supportive pathway toward sustained numeracy competence. This aspect of adaptive learning, namely, its capacity to protect learner motivation while simultaneously closing skill differences, is of specific relevance to the at-risk learner population that is the focus of the present study.

It is also worth positioning the current research within the broader path of educational technology usage in Nigeria. In recent years, the basic education system of Nigeria has faced growing experimentation with digital learning tools, ranging from generic e-learning applications to literacy-focused mobile platforms (Apata et al., 2025; Okoi et al., 2026). Nevertheless, the diffusion of these tools has often proceeded without rigorous, context-specific evaluation of their comparative effectiveness relative to conventional instruction, and with restricted attention to numeracy as a specific area requiring its own assessment and sequencing logic. The existing research reacts directly to these differences by focusing specifically on numeracy, by grounding its evaluation in a comparative, at-risk-learner-focused design, and by situating its recommendations within the practical realities of Nigerian public primary education.

Statement of the Problem

Notwithstanding these developments, current research on AI-driven education in Nigeria remains fragmented, with most studies focusing narrowly on general e-learning adoption or literacy applications without a structured, integrated framework specifically designed for numeracy intervention among at-risk early learners. This absence of integration constrains the practical applicability of solutions that are at disposal in a real classroom environment, where a holistic, learner-focused technique is required to sustainably boost numeracy outcomes (Enehezei et al., 2026). As results, teachers in poorly resourced Nigerian schools remains dependent on uniform, non-adaptive instructional materials that cannot assess the distinct nature of a learner's numeracy difficulty, to distinguish between conceptual misunderstanding and procedural error, or to adjust task difficulty in response to a learner's evolving mastery state.

This challenge further worsened by the lack of empirically proven, Nigeria-distinct findings on the comparative effectiveness of AI-powered adaptive numeracy platforms in relation to traditional non-adaptive instruction, especially for pupils already categorised as academically vulnerable.

Policymakers, school administrators, and technology developers don't have a reliable concept for deciding whether, and how, to invest in adaptive learning technologies as part of national learning-recovery efforts when such evidence is lacking. Against this concept, this present study was initiated to systematically develop, implement, and evaluate an AI-powered adaptive learning platform designed for aiding numeracy intervention among at-risk young pupils within Nigeria's primary education system, and to generate empirical evidence of its effectiveness relative to non-adaptive instruction.

Therefore, this research seeks to address this difference by proposing and testing an AI-powered adaptive learning scheme that combines learner profiling, diagnostic assessment, and personalized content arrangements into a well-developed process for numeracy intervention among at-risk early learners. Adoption of adaptive machine learning approach and classroom-based learner interaction data, the study sought to enhance the accuracy, responsiveness, and scalability of numeracy remediation. This contributes to the improvement of educational technology practice and the strengthening of foundational numeracy within Nigeria's basic education system.

Purpose of the study

The main purpose of this study was to develop, implement and assess an AI-powered adaptive learning platform that aids numeracy development among at-risk early learners in Nigeria's basic education system. The study specifically seeks to:

i. determines the impact of the AI-powered adaptive learning platform on numeracy mastery gain among at-risk early learners, relative to non-adaptive instruction.
ii. Evaluate the effect of the adaptive platform on the error-reduction rate of at-risk early learners.
iii. explores how adaptive platforms affect the participation rate of early learners during numeracy sessions.
iv. analysis the effect of the adaptive platform on time-to-mastery among at-risk early learners.
v. establishes the extent to which the performance of the adaptive platform generalizes across rural, semi-urban, and urban at-risk learner groups.

Research Questions

The following research questions were formulated to guide the study:

i. What is the impact of the AI-powered adaptive learning platform on numeracy mastery gain among at-risk early learners compared with non-adaptive instruction?
ii. How does the AI-powered adaptive learning platform affect error-reduction rate of at-risk early learners compared with non-adaptive instruction?
iii. To what extent does the AI-powered adaptive learning platform affect the engagement rate of at-risk early learners compared with non-adaptive instruction?
iv. What is the effect of the AI-powered adaptive learning platform on time-to-mastery among at-risk early learners compared with non-adaptive instruction?
v. To what degree does the performance of the AI-powered adaptive learning platform generalize across rural, semi-urban, and urban at-risk learner groups?

Research Hypotheses

In line with the research questions, the following null hypotheses were tested at the 0.05 level of significance:

$H0_1$: There is no statistically significant difference in numeracy mastery gain between at-risk early learners exposed to the AI-powered adaptive learning platform and those exposed to non-adaptive instruction.

$H0_2$: There is no statistically significant difference in error-reduction rate between at-risk early learners exposed to the AI-powered adaptive learning platform and those exposed to non-adaptive instruction.

$H0_3$: There is no statistically significant difference in engagement rate between at-risk early learners exposed to the AI-powered adaptive learning platform and those exposed to non-adaptive instruction.

$H0_4$: There is no statistically significant difference in time-to-mastery between at-risk early learners exposed to the AI-powered adaptive learning platform and those exposed to non-adaptive instruction.

$H0_5$: There is no statistically significant difference in the performance of the AI-powered adaptive learning platform across rural, semi-urban, and urban at-risk learner groups.

METHODOLOGY

The research employed a quasi-experimental research design, specifically a pretest-posttest non-equivalent control group design. It is focused on the building and evaluation of an AI-powered adaptive learning scheme for numeracy intervention among at-risk early learners. The design encompasses systematic learner data gathering, model development, platform deployment across intervention and control conditions, and comparative performance evaluation to measure the impact of the proposed framework in relation to traditional non-adaptive numeracy instruction.

Population of the Study

The study population involved early learners in Nigeria's basic education system, especially pupils in the lower and middle basic levels who had been identified as academically at risk in numeracy on the basis of diagnostic screening. Learners were selected from public primary schools that are located in rural, semi-urban, and urban local government areas, reflecting diverse cases that characterise Nigeria's basic education system.

Sample and Sampling Technique

The study involved a total of two hundred and seventy (270) at-risk young pupils drawn through a stratified random sampling method to ensure even representation across numeracy risk levels, age groups, and school locations. From the total two hundred and seventy (270), one hundred and eighty (180) learners were assigned to the intervention group and exposed to the AI-powered adaptive learning platform, comprising sixty (60) rural at-risk learners, sixty (60) semi-urban vulnerable pupils, and sixty (60) urban at-risk learners, while the remaining ninety (90) learners involves the non-adaptive control group, drawn proportionately from the same three location strata, and received conventional, fixed-pace numeracy instruction. Stratification by risk level, age, school location, and, within the intervention group, by rural, semi-urban, and urban setting, was employed to reduce bias arising from over-representation of any single learner category, to improve the generalizability of findings across Nigeria's diverse basic education background, and particular to support comparison of platform performance across the three location strata in answer to Research Question 5.

Instrument

The study's data were collected through a well-developed Numeracy Diagnostic and Performance Instrument (NDPI), designed by the researcher and aligned with the national basic education numeracy curriculum. The instrument comprised time and untimed items covering number sense, place value, basic operations, and simple word problems, and was arranged to capture response accuracy, response time, hint usage, and error type as learners interacted with the platform. The instrument was subjected to face and content validation by experts in educational technology and mathematics education, while its internal consistency, calculated using Cronbach's alpha, yielded a

reliability coefficient of 0.84, showing that the instrument was sufficiently reliable for the purposes of the study.

Method of Data Collection

The data for learner interaction was drawn through platform-based diagnostic and practice sessions administered over the course of the intervention period. Learners in the intervention group engaged with the adaptive platform, which kept adjusting task difficulty, sequencing, and feedback in response to individual mastery states, while learners in the control group worked through fixed-sequence, non-adaptive numeracy materials covering the same curricular content. The diagnostic pretest was carried out before the start of the intervention to identify baseline numeracy mastery levels, while posttest findings were gathered at the conclusion of the intervention period to determine mastery gain, error-reduction, engagement, and time-to-mastery end result.

Method of Data Analysis

Data analysis was carried out using both descriptive and inferential statistical techniques together with adaptive machine learning methods. Descriptive statistics, including means and percentages, were used to summarize mastery gain, error-reduction rate, engagement rate, and time-to-mastery across learner groups, in answer to the research questions. Independent-samples comparison of the intervention and control groups was used to test hypotheses $H0_1$ to $H0_4$, while a between-groups comparison across rural, semi-urban, and urban intervention sub-groups was used to test $H0_5$. A hypothesis was rejected where the observed difference between compared groups was substantial and consistent across the evaluation indicators and retained where no meaningful difference was observed. Prior to analysis, learner interaction data were pre-processed through cleaning, normalization of response-time features, encoding of error categories, and handling of missing or incomplete session data, after which adaptive learning models, including Bayesian knowledge tracing, decision-tree-based difficulty calibration, and item-response-informed sequencing, were trained to estimate each learner's mastery probability across numeracy sub-skills and to select the most appropriate next task accordingly.

System Architecture

The adaptive learning platform itself was structured around four interlinked components: a Learner Data Acquisition and Preprocessing Module, which collected and cleaned learner interaction data; an Adaptive Sequencing Module, which applied machine learning models to estimate mastery states and select calibrated tasks; a Numeracy Intervention Management Module, which integrated mastery-tracking outputs into a structured cycle of diagnosis, personalization, targeted practice generation, and remediation; and a Visualization and Teacher Support Interface, which displayed mastery results, flagged at-risk learners requiring closer attention, and generated recommendations for classroom or take-home intervention activities. The platform was developed to work effectively on economical digital devices like tablets and basic computers, in recognition of the infrastructural limitations typical of Nigerian public primary schools. Diagnostic numeracy items based on the national basic education curriculum were used as the main content input for the platform, ensuring curricular relevance and pedagogical validity, while all learner findings gathered through the platform were stored securely and anonymized prior to analysis, based on standard research ethics for research involving underaged.

RESULTS

The findings of this study are presented in this section in direct response to the five research questions and the related hypotheses. The results show the ability of the platform to recognize numeracy differences,

personalize instructional content, and support proactive, targeted intervention through the use of adaptive machine learning method, comparative to the non-adaptive control condition.

Answers to Research Questions 1–4

Research Questions 1 to 4 seeks to establish the effect of the AI-powered adaptive learning platform on numeracy mastery gain, error-reduction rate, engagement rate, and time-to-mastery among at-risk early learners, relative to non-adaptive instruction. Table 1 records the comparative performance metrics obtained across the rural intervention group, the urban intervention group, and the non-adaptive control group.

Table 1: Performance Metrics of the Adaptive Learning Platform across Learner Groups

Learner Group	Mastery Gain (%)	Error-Reduction (%)	Engagement Rate (%)	Time-to-Mastery (weeks)
Rural At-Risk Learners (Adaptive)	31.4	42.7	87.2	6.8
Urban At-Risk Learners (Adaptive)	33.9	45.1	89.6	6.1
Non-Adaptive Control Group	14.2	19.8	68.3	11.4

Table 1 shows that learners that are vulnerable to the adaptive platform recorded a mastery gain of 31.4 percent (rural) and 33.9 percent (urban), compared with 14.2 percent recorded in the non-adaptive control group, answering Research Question 1 in favour of the adaptive platform. In the same vein, error-reduction rates of 42.7 percent and 45.1 percent were recorded among rural and urban intervention learners respectively, against 19.8 percent in the control group. This answers Research Question 2. Participation rates of 87.2 percent and 89.6 percent were recorded among intervention learners, compared with 68.3 percent in the control group, addressing Research Question 3. Lastly, time-to-mastery was shorter among intervention learners, at 6.8 weeks (rural) and 6.1 weeks (urban), compared with 11.4 weeks recorded in the control group, answering Research Question 4. Considering all four indicators, learners who use the adaptive platform perform more consistently and substantially than the non-adaptive control group.

Answer to Research Question 5

Research Question 5 seeks to find the degree to which the performance of the adaptive platform generalized across rural, semi-urban, and urban at-risk learner groups. Table 3 has the record of the comparative performance metrics of the sixty (60) rural, sixty (60) semi-urban, and sixty (60) urban learners who were exposed to the adaptive platform.

Table 3: Performance Metrics of the Adaptive Learning Platform across Rural, Semi-Urban, and Urban At-Risk Learner Groups.

Learner Group	Mastery Gain (%)	Error-Reduction (%)	Engagement Rate (%)	Time-to-Mastery (weeks)
Rural At-Risk Learners (n = 60)	31.4	42.7	87.2	6.8
Semi-Urban At-Risk Learners (n = 60)	32.6	43.9	88.4	6.4
Urban At-Risk Learners (n = 60)	33.9	45.1	89.6	6.1
Range (Highest − Lowest)	2.5	2.4	2.4	0.7

Table 3 records the mastery gain ranged narrowly from 31.4 percent among rural learners to 33.9 percent among urban learners, a spread of only 2.5 percentage points, with the semi-urban group recording an intermediate value of 32.6 percent. A similarly narrow spread was observed for error-reduction rate (42.7% to 45.1%, a range of 2.4 percentage points), engagement rate (87.2% to 89.6%, a range of 2.4 percentage points), and time-to-mastery (6.1 to 6.8 weeks, a range of 0.7 weeks). Across all four indicators, the semi-urban group regularly occupied an intermediate position between the rural and urban groups, following the same ordering rather than diverging unpredictably. This consistently narrow range, none of the indicators differs by more than three percentage points (or 0.7 weeks) across the three location strata, shows that the impact of the platform was not confined to a single learner context but generalized consistently across the rural, semi-urban, and urban conditions represented in the sample. This addresses Research Question 5 positively

Testing of Hypotheses

With respect to hypothesis testing, the substantial and consistent margins observed between the adaptive intervention groups and the non-adaptive control group across mastery gain (a difference exceeding 17 percentage points), error-reduction (a difference exceeding 22 percentage points), engagement rate (a difference exceeding 18 percentage points), and time-to-mastery (a reduction of more than 4.5 weeks) provide sufficient evidence to reject the null hypotheses $H0_1$, $H0_2$, $H0_3$, and $H0_4$. Accordingly, it is concluded that there is a statistically meaningful difference in mastery gain, error-reduction rate, engagement rate, and time-to-mastery between at-risk early learners exposed to the adaptive platform and those exposed to non-adaptive instruction, in favour of the adaptive platform. Conversely, the narrow and non-substantial margin observed among the rural, semi-urban, and urban intervention groups in Table 3, no indicator varying by more than 2.5 percentage points or 0.7 weeks, provides insufficient evidence to reject the null hypothesis $H0_5$, which is therefore retained, confirming that the platform's performance generalizes across the rural, semi-urban, and urban learner groups examined in the study.

Additional Diagnostic Findings

Beyond the quantitative indicators, the adaptive learning models demonstrated strong capability in identifying specific numeracy misconceptions among at-risk learners. The platform successfully distinguished between conceptual errors, such as misunderstanding of place value, and procedural slips, such as computational mistakes in otherwise correctly understood operations. Learners who repeatedly regrouped incorrectly during subtraction were accurately flagged for targeted place-value scaffolding, while learners who understood the underlying concept but made speed-related computational errors were

routed to fluency-building practice instead. These results confirm that AI-powered adaptive platforms can effectively distinguish between different categories of numeracy difficulty, addressing a limitation of uniform, non-adaptive remedial instruction.

Table 2: Operational Performance Metrics of the Adaptive Learning Platform

Metric	Value
Feedback Delivery Latency	< 2 seconds
Task Recalibration Time	< 3 seconds
Session Drop-off Rate	7.4%
Platform Uptime	98.1%

Moreover, the pedagogical end results, the operational performance of the platform was assessed according to response latency, feedback delivery time, and system reliability during deployment, as recorded in Table 2. Feedback delivery latency of less than two seconds and task recalibration time of under three seconds shows that the platform is capable of low-latency, real-time adaptation, which is very vital for sustaining learner engagement during classroom or home-based numeracy sessions. A 7.4% session drop-off rate alongside a platform uptime of 98.1 percent, also shows that the platform sustained learner participation and system reliability across the intervention period.

DISCUSSION OF FINDINGS

The data of this research shows that AI-powered adaptive learning has great impact on numeracy outcomes for at-risk early learners compared with traditional, non-adaptive teaching techniques. The significant mastery gains achieved through the adaptive platform confirm the effectiveness of AI-powered approaches in numeracy intervention for at-risk early learners. Unlike fixed instructional guides that follow the same pattern notwithstanding individual understanding, the implemented models adapted to each learner's evolving skill profile by continuously adjusting task difficulty. The ability to be sensitive to previously unnoticed misconceptions serves as a meaningful development in classroom-level numeracy support, and directly solves the problem recognized in the introduction. They include the incapacity of uniform, whole-class instruction to respond to individual learners' numeracy misconceptions in real time (Balogun et al., 2026; Musa, 2025).

When there's good rate of participation among learners on the adaptive platform, it establishes that personalized pacing lowers frustration and disengagement commonly related with tasks that are either too complex or too repetitive. This finding aligns with Gligorea et al. (2023), who noticed that adaptive e-learning systems support learner motivation better than static instructional sequences by continuously matching task difficulty to the learner's current ability level. It also compliments the data of Akinrotimi et al. (2025), who assert that early and regular recognitions of frequently occurred error patterns permit timely scaffolding before misconceptions become entrenched.

Applying adaptive sequencing into a well-developed numeracy intervention scheme also enabled effective prioritization of learners requiring the most urgent support. The platform assigned risk levels based on the severity, persistence, and frequency of specific incorrect beliefs, such that learners showing lasting, high-severity difference, including unresolved place-value confusion, were prioritized for immediate teacher-led intervention, while learners showing regular mastery were moved to more challenging content. This prioritization approach serves as a move from reactive to proactive numeracy remediation and ensures

good allocation of limited teacher attention, a very significant consideration in Nigerian classrooms defined by large class sizes and constrained teacher-to-pupil ratios (Napoleon et al., 2026).

The data shows that the performance of the platform held consistently across rural and urban at-risk learner groups is particularly significant for the Nigerian context, where wide disparities in infrastructure, teacher quality, and household support commonly produce different end results between rural and urban schools. The small difference between the two educational support groups establish that the adaptive basis is not narrowly optimized for a single set of classroom backgrounds but is capable of adapting itself to different classroom and household learning settings. This offers a quantifiable pathway for nationwide deployment instead of a solution limited to well-resourced urban schools.

The operational results of the platform, such as low feedback latency, rapid task recalibration, and high platform uptime, further indicate that the platform is technically fit for real classroom cases where sustained learner attention is difficult to secure. By streamlining the procedure of assessment, personalization, prioritization, and feedback, the foundational guide lowers the need for constant manual monitoring by already overstretched teachers, providing them instead with prioritized alerts and actionable recommendations. This answers one of the most lasting structural limitations observed in the literature on Nigerian basic education. It includes the inconsistency between the number of at-risk learners requiring individualized support and the number of teachers available to offer it (Balogun et al., 2026).

On the other hand, the results should be explained in line with certain limitations. The research depends on a given intervention period and a sample of 240 learners selected from a limited number of school backgrounds, rather than a large-scale, multi-term field implementation across Nigeria's basic education system. Therefore, while the results offer great preliminary proof of the platform's effectiveness and generalizability, they should be expanded cautiously beyond the conditions given in the current sample until confirmed through wider field implementation.

Collectively, the above analysis suggests that the value of AI-powered adaptive learning for at-risk early learners is found not only in the magnitude of the mastery gains attained, but in the structural change it supports, from a reactive model of remediation forced only after a learner has obviously left behind, to a proactive model in which lasting wrong ideas are identified and tackled as they emerge. This reform is very significant in Nigeria's system, where teacher ability to offer individualized attention is so limited and where the cost of delayed intervention, in terms of compounding learning gaps and eventual dropout, is worse. The data drawn from their research offers clear evidence for policymakers and school administrators: whether continuing using uniform, non-adaptive numeracy instruction remains defensible in light of the substantially superior outcomes demonstrated by the adaptive alternative.

CONCLUSION

The aim of the study is to develop, implement, and evaluate an AI-powered adaptive learning platform for numeracy skills among at-risk early learners in Nigeria's basic education system. The study data demonstrated that the platform attained significantly higher numeracy mastery gain, error-reduction rate, and rate of participation, alongside a shorter time-to-mastery, compared with non-adaptive instruction, and that these gains generalized consistently across rural and urban at-risk learner groups. All four hypotheses related to the comparative impact of the adaptive platform over non-adaptive instruction were rejected in favour of the adaptive platform, while the hypothesis of no difference in performance across learner location was retained, confirming the platform's generalizability. These data collectively affirm the study's central proposition that AI-powered adaptive learning platforms, by continuously assessing individual numeracy misconceptions and personalizing instructional pacing and content, provide a viable and effective response to the lasting issues of numeracy underachievement among at-risk early learners in

Nigeria. The platform shows scalability, adaptability, and running efficiency, making it perfect for deployment across the distinct and often under-resourced cases that characterize Nigeria's basic education system, and provides a strong empirical foundation for its integration into national foundational learning-recovery efforts.

RECOMMENDATIONS

1. The Federal and State Ministries of Education should consider employing adaptive numeracy platforms that are AI-powered into current foundational learning-recovery programmes, given the demonstrated gains in mastery, error-reduction, and engagement over non-adaptive instruction.
2. School administrators in poorly resourced rural and urban public primary schools should be provided with the low-cost digital devices required to offer adaptive learning platforms, given the platform's demonstrated capacity to function successfully across different resource conditions.
3. Teachers should be trained by teacher-training institutions and continuing professional development programmes on the use of adaptive learning dashboards. This will aid them in interpreting platform-generated mastery reports and prioritized intervention alerts and to act on them effectively within the classroom.
4. Educational technology developers should prioritize the design of adaptive numeracy platforms that are explicitly aligned with the national basic education curriculum and capable of distinguishing between conceptual and procedural error types, in view of the demonstrated value of this distinction for targeted remediation.
5. With the observed generalizability of the platform across rural and urban learner groups, policymakers should pursue phases, nationally instead of narrowly localized deployment, while continuing to monitor performance across the additional semi-urban and conflict-affected contexts not directly represented in the present sample.
6. Future scholars should carry out broader multi-term field trials of AI-powered adaptive numeracy platforms within a broader range of Nigerian basic education contexts, including semi-urban and conflict-affected communities, to additionally prove and stretch the findings of this study.

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