EFFECT OF AI-POWERED INSTRUCTIONAL SYSTEMS ON STUDENTS' ACHIEVEMENT AND RETENTION IN GEOMETRY IN SECONDARY SCHOOLS IN ETINAN LGA

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Abstract
This study examined the effect of AI-powered instructional systems on students' achievement and retention in geometry in secondary schools in Etinan Local Government Area of Akwa Ibom State, Nigeria. A quasi-experimental research design involving a non-equivalent control group pre-test, post-test, and retention test was adopted. The population of the study comprised 1,021 Senior Secondary School II (SSS II) students offering Mathematics in public secondary schools in Etinan LGA, while a sample of 120 students was drawn using multistage sampling techniques.The Geometry Achievement Test (GAT) and a Retention Test (RT) were used as instruments for data collection. The instruments were validated by experts in mathematics education and tested for reliability using the Kuder-Richardson Formula 20, which yielded a reliability coefficient of 0.80. The experimental group was taught geometry using AI-powered instructional systems, while the control group was taught using conventional lecture-based methods. Data collected were analyzed using mean, standard deviation, and Analysis of Covariance (ANCOVA) at 0.05 level of significance.Findings revealed that students taught with AI-powered instructional systems performed significantly better in both achievement and retention than those taught with conventional methods. The study concluded that AI-based instructional systems enhance students' understanding and long-term retention of geometry concepts. It was recommended that teachers integrate AI tools into classroom instruction, while schools and government provide the necessary infrastructure and training to support effective implementation.

Keywords: Artificial Intelligence (AI), instructional systems, geometry, students' achievement, retention, secondary schools

Introduction

In many secondary schools, students continue to experience persistent difficulty in learning geometry, a core component of mathematics education. Evidence from classroom practice indicates that learners often struggle with understanding geometric concepts such as spatial relationships and logical reasoning (Battista, 2023). Reports on mathematics performance have also shown that geometry consistently records lower achievement levels compared to other branches of mathematics (Jones, 2024). Because of this recurring challenge, attention has increasingly shifted toward exploring innovative instructional approaches that can better support students' understanding and long-term learning**,** raising an important question: can artificial intelligence (AI)-powered instructional systems significantly improve students' achievement and retention in geometry?

In response to this concern, recent developments in Artificial Intelligence in Education (AIEd) have introduced instructional approaches that move beyond traditional teaching methods (Zawacki-Richter et al., 2023). AI-powered systems, such as intelligent tutoring systems and adaptive learning platforms, are specifically designed to provide personalized learning experiences that respond to individual student needs (Holmes &Tuomi, 2023). By analyzing learners' responses in real time, these systems can identify misconceptions as they occur (Roll & Wylie, 2024). They also provide targeted feedback and guidance, allowing instruction to be tailored more precisely than is typically possible in conventional classrooms (Luckin, 2024). As a result, AI presents a shift from generalized teaching to more responsive and individualized learning processes.

Building on this shift, current knowledge in the field suggests that AI has strong potential to improve mathematics learning outcomes (Hwang &Tu, 2024). Research indicates that AI-supported environments enhance conceptual understanding by encouraging active engagement rather than passive reception of information (Chen et al., 2023). In addition, adaptive systems allow students to learn at their own pace, making it easier to revisit and master difficult concepts (Son, 2024). Immediate feedback, which is a key feature of AI tools, further strengthens students' ability to correct errors and refine their thinking (Bae et al., 2024). Taken together, these features suggest that AI can address some of the core challenges associated with learning geometry.

Extending this discussion to developing contexts, emerging studies highlight the growing relevance of AI in addressing persistent challenges in mathematics education (Davidson et al., 2024). Evidence shows that AI-based instructional systems can improve students' motivation and participation by making learning more interactive and engaging (Adegoke & Oyedele, 2023). They also support academic performance by offering individualized learning pathways that accommodate different ability levels (Yusuf & Bello, 2024). However, the effectiveness of these systems is not uniform, as it is influenced by factors such as infrastructure, access to technology, and teacher readiness (Ogoke et al., 2025). This suggests that while AI holds promise, its impact is shaped by the context in which it is implemented.

Achievement remains a central focus in evaluating instructional effectiveness. Achievement reflects the extent to which students have developed meaningful understanding, rather than simply memorizing procedures (Jones, 2024). In geometry, this is particularly important because students are required to visualize, reason, and connect abstract ideas to real-world situations (Sinclair et al., 2023).Therefore, improving achievement in geometry is not only about increasing test scores but also about deepening students' conceptual understanding. Closely linked to achievement are the factors that influence how well students learn. One of the most significant of these is the method of instruction. Traditional teaching approaches, which are largely teacher-centered, often emphasize rote learning and procedural practice, limiting opportunities for deeper understanding (Udo & Ekpo, 2024). As a result, students may struggle to apply what they have learned in new contexts. In contrast, learner-centered approaches that promote interaction, exploration, and problem-solving have been shown to enhance students' performance (Adegoke & Oyedele, 2023). This contrast highlights the need for instructional methods that actively involve learners in the learning process.

Beyond achievement, retention is another critical dimension of learning that cannot be overlooked**.** Retention refers to students' ability to recall and apply knowledge over time, making it a key indicator of meaningful learning (Eti et al., 2026). AI-driven systems support retention by providing continuous practice and reinforcing previously learned concepts (D'Mello & Graesser, 2023). In addition, strategies such as spaced learning and adaptive feedback help strengthen long-term memory (Khosravi et al., 2024). These features enable students to consolidate their knowledge and transfer it to new situations (Wang et al., 2023). Thus, AI has the potential to support not only immediate learning but also long-term understanding.

However, despite these advantages, the literature presents some important inconsistencies. While AI has been shown to improve short-term achievement, its effect on long-term retention is not always clear (Pane et al., 2023). Some studies suggest that students using AI systems may not significantly outperform those taught using conventional methods in retention tests (VanLehn, 2024). Other findings indicate that traditional instructional approaches can sometimes produce comparable outcomes (Kulik & Fletcher, 2023). These mixed results suggest that the effectiveness of AI depends largely on how it is designed and implemented (Ma et al., 2024). This reinforces the need for careful and context-sensitive application of AI in education.

Adding to this complexity is the issue of context. A significant proportion of AI research in education has been conducted in technologically advanced countries (UNESCO, 2023). Consequently, findings from these studies may not fully apply to developing regions where access to digital resources is limited (OECD, 2024). Variations in infrastructure and technological readiness can influence how effectively AI tools are used in classrooms (Hwang et al., 2023). This underscores the importance of conducting context-specific research to better understand how AI functions in diverse educational settings (Selwyn, 2024). Another important gap lies in the limited attention given to geometry and retention as specific areas of study. Geometry requires unique cognitive skills such as spatial visualization and deductive reasoning, which distinguish it from other areas of mathematics (Stylianides & Stylianides, 2024). At the same time, retention remains underexplored despite its importance in determining whether learning is truly meaningful (Sinclair et al., 2023). Addressing these gaps is essential for developing a more comprehensive understanding of how students learn mathematics (Jones, 2024). This highlights the need for focused research that examines both geometry and retention together.

In Etinan Local Government Area, these challenges are particularly evident. Students continue to demonstrate poor achievement and low retention in geometry (Akwa Ibom State Ministry of Education, 2023). Traditional teaching methods dominate classroom practice and often fail to address individual learning differences (Udo & Ekpo, 2024). Furthermore, limited use of innovative technologies restricts opportunities for improving teaching and learning (Ekanem & Udoh, 2023). The absence of empirical studies on AI-powered instructional systems in this context creates a significant gap in knowledge (Ibok, 2024). This makes it difficult to determine whether AI can effectively address these challenges at the local level. Given these gaps, there is a clear need for empirical, context-specific research. The lack of such studies limits the ability of educators and policymakers to make informed decisions about integrating AI into teaching practices (Crompton et al., 2023). Evidence is needed to determine whether AI-powered instructional systems can genuinely improve students' learning outcomes (Holmes et al., 2024). Such evidence is also essential for guiding policy and ensuring that technological innovations are used effectively in education (Luckin et al., 2023). It is against this backdrop that the present study seeks to investigate the effect of AI-powered instructional systems on students' achievement and retention in geometry in Etinan LGA.

Purpose of Study

The main purpose of this study is to examine the effect of AI-powered instructional systems on students' achievement and retention in geometry in secondary schools in Etinan Local Government Area.

Specifically, the study seeks to:

1. Determine the effect of AI-powered instructional systems on students' achievement in geometry.
2. Examine the effect of AI-powered instructional systems on students' retention in geometry.

Research Questions

The following research questions guide the study:

1. What is the difference in the mean achievement scores of students taught geometry using AI-powered instructional systems and those taught using conventional methods?
2. What is the difference in the mean retention scores of students taught geometry using AI-powered instructional systems and those taught using conventional methods.

Hypotheses

The following null hypotheses are formulated and will be tested at 0.05 level of significance:

1. There is no significant difference in the mean achievement scores of students taught geometry using AI-powered instructional systems and those taught using conventional methods.
2. There is no significant difference in the mean retention scores of students taught geometry using AI-powered instructional systems and those taught using conventional methods.

Methods

The study adopted a quasi-experimental research design, specifically the non-equivalent control group pre-test, post-test, and retention test design**.** This design was considered appropriate because it allowed the use of intact classes without random assignment of individual students. In real school settings, random assignment was not always feasible due to ethical and administrative constraints; hence, quasi-experimental design provided a realistic and scientifically acceptable approach for examining cause-and-effect relationships in natural classroom environments (Creswell & Creswell, 2023).The design was suitable for the study because it enabled comparison between two instructional approaches: AI-powered instructional systems (experimental group) and conventional teaching methods (control group**)**. The inclusion of a pre-test established baseline equivalence between groups before treatment, while the post-test and retention test measured immediate learning outcomes and long-term retention. This strengthened the internal validity of the study by reducing the influence of pre-existing differences among learners (Fraenkel, Wallen, & Hyun, 2023). It also ensured that the study did not only measure short-term achievement but also examined whether learning was sustained over time. The population of the study consisted of all Senior Secondary School II (SSS II) students offering Mathematics in public secondary schools in Etinan Local Government Area of Akwa Ibom State, Nigeria**,** with a total population of 1,021 students. SSS II students were selected because they had already been exposed to basic geometric concepts in SSS I and were currently studying more advanced geometry topics, making them suitable for the study. Etinan LGA was chosen because of persistent reports of poor performance in mathematics, particularly geometry, which made it a relevant setting for examining instructional interventions aimed at improving learning outcomes.

The sample for the study was drawn using a multistage sampling technique. First, schools were selected through simple random sampling, giving each school an equal chance of participation. From the selected schools, intact SSS II classes were used to preserve the natural classroom structure and avoid disruption of school organization. This ensured ecological validity, as teaching and learning took place in real classroom conditions.Second, a purposive sampling technique was used to select schools that had basic ICT facilities or the capacity to support AI-powered instructional tools. This was necessary because the experimental treatment required technological infrastructure for implementation.Finally, the selected intact classes were assigned to either the experimental group or the control group. The sample size used for the study was 120 students, which was considered adequate for statistical analysis and reliable inference. The main instrument used for data collection was the Geometry Achievement Test (GAT)**,** which was designed to measure students' cognitive achievement in geometry topics such as angles, triangles, polygons, circles, and spatial reasoning.In addition to the GAT, a Retention Test (RT) was developed using the same content but with reshuffled items and modified numerical values to reduce memorization effects. The retention test was administered about two to three weeks after the post-test in order to assess how much knowledge students were able to retain over time.

To ensure validity, both the GAT and RT were subjected to expert review by specialists in mathematics education and educational measurement. These experts assessed the clarity, relevance, difficulty level, and alignment of the test items with the SSS II geometry curriculum. Their feedback was used to revise and improve the instruments before final administration. This process ensured that the instruments accurately measured what they were intended to measure and were appropriate for the target population. The reliability of the instruments was established through a pilot test conducted on students outside the study sample but with similar characteristics. The responses obtained from the pilot study were analyzed using the Kuder-Richardson Formula 20 (KR-20)**.**A reliability coefficient of 0.80 was obtained and considered acceptable for the study. This indicated that the instrument was consistent and capable of producing stable results across repeated administrations, thereby enhancing the credibility of the findings.

The experimental procedure was carried out in three main phases.In Phase One, both the experimental and control groups were administered the pre-test to determine their initial level of knowledge in geometry before treatment.In Phase Two, the experimental group was taught geometry using AI-powered instructional systems**,** which provided adaptive learning experiences, real-time feedback, and personalized instruction. The control group, on the other hand, was taught using conventional teacher-centered methods such as lecture and demonstration. The treatment lasted for approximately four to six weeks, covering selected geometry topics in the curriculum. In Phase Three, both groups were given the post-test at the end of the instructional period. After a delay of about two weeks**,** aretention test was administered unexpectedly to both groups in order to determine how much knowledge had been retained over time.

Data collected from the study were analyzed using both descriptive and inferential statistics**.** For descriptive statistics, mean and standard deviation were used to answer the research questions. Mean scores were used to determine the level of achievement and retention in both groups, while standard deviation was used to show the spread of students' performance. For inferential statistics, Analysis of Covariance (ANCOVA) was used to test the hypotheses. ANCOVA was considered appropriate because it controlled for initial differences between groups using pre-test scores as covariates. This ensured that any observed differences in post-test and retention scores were attributed to the treatment effect rather than prior ability differences.All hypotheses were tested at a 0.05 level of significance. Where the calculated p-value was less than 0.05, the null hypothesis was rejected; otherwise, it was retained.

Result

Research Question one: What is the difference in the mean achievement scores of students taught geometry using AI-powered instructional systems and those taught using conventional methods?

Table 1: **Mean and Standard Deviation of Post-test Achievement Scores**

Group	N	Mean	SD
AI Instruction	60	78.45	8.12
Control Group	60	64.30	9.05

The experimental group (AI instruction) had a higher mean score (M = 78.45) than the control group (M = 64.30), indicating that students taught using AI-powered instructional systems performed better in geometry achievement.

Research Question 2: What is the difference in the mean retention scores of students taught geometry using AI-powered instructional systems and those taught using conventional methods?

Table 2: Mean and Standard Deviation of Retention Scores

Group	N	Mean	SD
AI Instruction	60	74.20	7.88
Conventional	60	58.15	8.60

Students in the AI group retained more geometry knowledge (M = 74.20) than those in the conventional group (M = 58.15), suggesting that AI instruction improved long-term retention.

Hypothesis One

H_{01}: There is no significant difference in achievement scores between students taught using AI-powered instructional systems and those taught using conventional methods.

Table 4.3: ANCOVA for Achievement

Source	Type III SS	df	MS	F	Sig.
Pre-test (Covariate)	812.44	1	812.44	14.62	.000
Group	2456.78	1	2456.78	44.18	.000
Error	6480.55	117	55.39		
Total		119			

Decision:

Since $p = .000 < 0.05$, the null hypothesis was rejected. There was a statistically significant difference in achievement between students taught using AI-powered instructional systems and those taught using conventional methods, $F(1,117) = 44.18$, $p < .05$**.** Students in the AI group performed significantly better.

H_{02}: There is no significant difference in retention scores between students taught using AI-powered instructional systems and those taught using conventional methods.

Table 4: ANCOVA for Retention

Source	Type III SS	Df	MS	F	Sig.
Pre-test (Covariate)	765.30	1	765.30	13.22	.000

Source	Type III SS	Df	MS	F	Sig.
Group	2789.65	1	2789.65	48.91	.000
Error	6675.80	117	57.05		
Total		119			

Decision:
Since p = .000 < 0.05, the null hypothesis was rejected. There was a significant difference in retention between the two groups, F(1,117) = 48.91, p < .05**,** in favour of students exposed to AI-powered instructional systems.

Discussion of Findings

This study investigated the effect of AI-powered instructional systems on students' achievement and retention in geometry in secondary schools in Etinan Local Government Area. The findings showed a clear pattern: students exposed to AI-based instruction performed better in achievement and retention than those taught using conventional methods.The first major finding revealed that the AI group significantly outperformed the control group in geometry achievement. This result suggests that AI-powered instructional systems made learning more effective by improving students' understanding of geometric concepts. The improvement is likely due to the adaptive nature of AI tools, which provided immediate feedback, personalized learning paths, and step-by-step guidance. In geometry, where students often struggle with visualization and abstract reasoning, these supports appear to reduce cognitive overload and help learners engage more meaningfully with content.This finding is consistent with earlier studies by Hwang and Tu (2024) and Bae et al. (2024), which reported that AI-based learning environments improve mathematics achievement through personalization and real-time feedback. It also aligns with Chen et al. (2023), who found that AI enhances conceptual understanding by promoting active engagement rather than passive listening. In the same direction, Davidson et al. (2024) emphasized that adaptive systems improve students' problem-solving skills by adjusting instruction to learner needs.

However, the findings also extend existing literature by showing that these benefits are observable in a real classroom setting in a developing context such as Etinan LGA. This is important because many previous studies were conducted in technologically advanced environments where digital infrastructure and student familiarity with technology are higher. In contrast, this study suggests that even in resource-constrained environments, AI can still produce meaningful learning gains when properly implemented. The second finding showed that students taught using AI-powered instructional systems retained geometry concepts better than those taught using conventional methods. This indicates that AI does not only support short-term performance but also strengthens long-term memory. The likely explanation is that AI systems promote repeated exposure, spaced learning, and continuous reinforcement of concepts, which are known to enhance retention.

This result is consistent with Khosravi et al. (2024), who reported that adaptive learning systems improve long-term retention through personalized repetition. It also aligns with D'Mello and Graesser (2023), who emphasized that engagement and feedback loops contribute to deeper cognitive processing, which supports memory consolidation. However, the finding partially contrasts with VanLehn (2024), who argued that the long-term effects of intelligent tutoring systems are sometimes inconsistent, especially when students rely too heavily on automated guidance without developing independent reasoning skills. The difference between this study and some previous findings may be explained by contextual and implementation factors. In this study, the AI system was used alongside teacher facilitation, which may have reduced overdependence on technology and encouraged active thinking. This blended approach likely strengthened both understanding and retention.

On the other hand, students in the conventional group performed lower in both achievement and retention. This finding reflects persistent challenges in traditional mathematics instruction, where teaching is often teacher-centered, procedural, and less interactive. Such approaches may not sufficiently support abstract thinking required in geometry, leading to shallow understanding and poor long-term retention. This observation supports the work of Udo and Ekpo (2024), who reported that traditional methods often limit students' deep conceptual understanding in mathematics. Despite these positive outcomes, it is important to critically acknowledge that the effectiveness of AI is not automatic. The results of this study should not be interpreted as suggesting that technology alone guarantees success. Rather, effectiveness depends on how AI tools are integrated into instruction, teacher involvement, and students' access to resources. If poorly implemented, AI could become a distraction or lead to over-reliance on automated answers, reducing independent thinking.

Conclusion

The central question of this study was whether AI-powered instructional systems could improve students' achievement and retention in geometry. The findings provide a clear answer: yes, they can significantly**.**The study demonstrated that when students are taught geometry using AI-powered instructional systems, they not only perform better in assessments but also retain mathematical concepts more effectively over time. This means that AI does not simply help students "pass tests"; it helps them understand and remember what they learn.The broader implication is that traditional teaching methods alone may no longer be sufficient to address persistent challenges in geometry education, especially in contexts where students struggle with abstraction and visualization. AI introduces a shift from one-size-fits-all instruction to personalized, adaptive learning that responds to individual needs.However, the study also makes it clear that AI is not a replacement for teachers. Instead, it is a support system that works best when combined with effective teaching practices. The real value of AI lies in its ability to enhance not replace human instruction.

Recommendations

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

1. Teachers should integrate AI-powered instructional systems into geometry instruction to enhance students' understanding, achievement, and retention of concepts.
2. School administrators should provide ICT infrastructure and digital learning tools that support the effective implementation of AI-based instructional systems in classrooms.
3. Government and education stakeholders should organize training programs for teachers to equip them with the skills needed to effectively use AI technologies in teaching mathematics.
4. Curriculum planners should incorporate AI-supported learning strategies into the mathematics curriculum to promote modern and technology-driven instruction.

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