



Intelligent Tutoring Instructional Strategy and Its Effects on Academic Achievement in Mathematics Among Secondary School Students in Osun State, Nigeria

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ABSTRACT

This study investigated the effects of Intelligent Tutoring Instructional Strategy (ITIS) on academic achievement in Mathematics among secondary school students in Osun State, Nigeria. The research adopted a quasi-experimental design, specifically the pretest-posttest non-equivalent control group design. The sample consisted of 240 senior secondary school two (SS2) students from four purposively selected secondary schools in Osun State. Two schools were assigned to the experimental group (ITIS) while two served as the control group (conventional teaching method) for an eight-week intervention period. Data were collected using the Mathematics Achievement Test (MAT) with a reliability coefficient of 0.86 determined through Kuder-Richardson formula 20. Data analysis was performed using Mean, Standard Deviation, Analysis of Covariance (ANCOVA), and t-test at 0.05 level of significance. Results revealed that students exposed to ITIS performed significantly better than those taught using conventional methods ($F(1, 237) = 168.45, p < 0.05, \text{partial } \eta^2 = 0.415$). The study found no significant difference in achievement between male and female students taught using ITIS ($t = -0.231, p > 0.05$). Additionally, there was no significant interaction effect of instructional strategy and gender on students' achievement in Mathematics ($F = 2.94, p = 0.088$), although the p-value approached significance, suggesting a trend warranting further investigation. The study concluded that ITIS is more effective than conventional teaching methods in improving students' academic achievement in Mathematics. It was recommended that Mathematics teachers should integrate intelligent tutoring systems into their instruction to enhance students' academic performance. The government should provide adequate and necessary technological infrastructure to facilitate the implementation of ITIS in secondary schools.

Keywords: Intelligent Tutoring System, Instructional Strategy, Mathematics Academic Achievement, Secondary Schools, Osun State.

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1. INTRODUCTION

The quality of education in any nation is fundamental to its technological, economic, and social development. In Nigeria, the secondary education sector plays a crucial role in preparing students for



higher education and developing the human resources necessary for national development. Mathematics education is particularly essential in this preparation as it provides foundational knowledge for various careers in engineering, computer science, economics, physical sciences, and technology-related fields (Adegoke, 2021). However, despite the importance of Mathematics in the secondary school curriculum, students' academic achievement in the subject has consistently remained below expectations.

National examination results from the West African Examinations Council (WAEC) and the National Examinations Council (NECO) over the past decade reveal persistent poor performance in Mathematics among Nigerian students. In Osun State specifically, the trend has been particularly concerning, with less than 35% of students obtaining credit passes in Mathematics in the Senior School Certificate Examinations between 2018 and 2022 (WAEC, 2022, Table 3.4, p. 47). This poor performance has been attributed to various factors, including mathematics anxiety, inadequate qualified teachers, lack of instructional materials, teacher-centered pedagogical approaches, and students' negative attitudes toward the subject (Okonkwo & Obielodan, 2021).

Conventional teaching methods, operationally defined in this study as teacher-centered approaches characterized by lecture-based instruction, chalkboard demonstrations, teacher-worked examples, and whole-class question-and-answer sessions with limited individualized feedback, are predominantly used in Nigerian secondary schools. These approaches often fail to accommodate individual learning differences, provide immediate feedback, or engage students in active problem-solving processes (Abakpa & Agbo-Egwu, 2020). Consequently, there has been a growing call for innovative and learner-centered instructional strategies that can address these limitations and improve students' academic achievement in Mathematics.

The emergence of educational technology has created opportunities for transforming teaching and learning processes, in ways that were previously impossible. Among these technological innovations, Intelligent Tutoring Systems (ITS) represent a significant advancement in personalized learning. Intelligent Tutoring Instructional Strategy (ITIS) refers to the pedagogical approach that utilizes computer-based systems equipped with artificial intelligence to provide individualized instruction and feedback to students (Kulik & Fletcher, 2020). These systems adapt to individual learners' needs, pace, and learning styles, offering customized content, practice opportunities, and immediate corrective feedback.

ITS incorporates four main components: the domain model (containing the mathematical knowledge to be learned), the student model (tracking individual student progress and understanding), the tutoring model (determining instructional strategies), and the user interface (facilitating interaction between the student and the system) (VanLehn, 2021). The integration of these components enables the system to function similarly to a human tutor, diagnosing students' misconceptions, providing scaffolded support, and adjusting instruction based on students' responses. Research in developed countries has demonstrated the effectiveness of intelligent tutoring systems in improving students' academic achievement across various subjects, particularly in Mathematics (Salloum et al., 2021).



However, in the Nigerian context, particularly in Osun State, there is limited empirical evidence regarding the effectiveness of ITIS in improving Mathematics achievement among secondary school students. This study therefore, examined the effects of Intelligent Tutoring Instructional Strategy on academic achievement in Mathematics among secondary school students in Osun State, Nigeria, addressing the gap in knowledge regarding technology-enhanced personalized learning in the Nigerian educational context, with particular attention to gender differences.

This study was guided by the following specific objectives:

1. To determine the difference in the academic achievement of secondary school students taught Mathematics using Intelligent Tutoring Instructional Strategy (ITIS) and those taught using conventional teaching methods in Osun State, Nigeria.
2. To examine the difference in the academic achievement of male and female secondary school students taught Mathematics using Intelligent Tutoring Instructional Strategy (ITIS) in Osun State, Nigeria.
3. To ascertain the interaction effect of instructional strategy (ITIS vs. conventional) and gender on secondary school students' academic achievement in Mathematics in Osun State, Nigeria.

1.1 Research Questions

The following research questions guided the study:

1. What is the difference in the mean academic achievement scores of students taught Mathematics using Intelligent Tutoring Instructional Strategy and those taught using conventional teaching methods?
2. What is the difference in the mean academic achievement scores of male and female students taught Mathematics using the Intelligent Tutoring Instructional Strategy?
3. What is the interaction effect of instructional strategy and gender on students' mean academic achievement scores in Mathematics?

1.2 Research Hypotheses

The following null hypotheses were tested at the 0.05 level of significance:

- **H0₁**: There is no significant difference in the mean academic achievement scores of students taught Mathematics using Intelligent Tutoring Instructional Strategy and those taught using conventional teaching methods.
- **H0₂**: There is no significant difference in the mean academic achievement scores of male and female students taught Mathematics using the Intelligent Tutoring Instructional Strategy.
- **H0₃**: There is no significant interaction effect of instructional strategy and gender on students' academic achievement in Mathematics.

2. LITERATURE REVIEW

2.1 Theoretical Framework

Adaptive Learning Theory states that instruction is most effective when tailored to individual prior knowledge, pace, and needs (Vandewaetere et al., 2021). Intelligent tutoring systems operationalize this by continuously assessing knowledge and adjusting content and difficulty to maintain appropriate challenge levels (Rasheed et al., 2020).



In mathematics, where topics build cumulatively, adaptive instruction is especially valuable for identifying gaps and providing targeted remediation. Cognitive Load Theory distinguishes intrinsic (material complexity), extraneous (instructional design), and germane load (schema construction). Effective instruction manages these by reducing extraneous load and optimizing intrinsic load (Paas & van Merriënboer, 2020). Intelligent tutoring systems manage cognitive load through adaptive scaffolding, worked examples, immediate feedback, and progressive difficulty, breaking complex problems into sub-goals (Kalyuga & Singh, 2021).

The Zone of Proximal Development (ZPD) theory proposes learning is most effective when instruction is pitched slightly beyond learners' independent capability but within their capability with appropriate scaffolding (Shabani et al., 2020). Effective scaffolding involves contingency (adjusting support based on performance), fading (gradually reducing support), and transfer of responsibility. Intelligent tutoring systems operationalize ZPD principles by providing adaptive scaffolding calibrated to individual capabilities and reducing scaffolding as students demonstrate mastery (Ritter et al., 2020).

The three theories provide complementary perspectives on why and how intelligent tutoring systems enhance mathematics learning.

2.2 Empirical Review

2.2.1 Intelligent Tutoring Systems and Mathematics Achievement

Intelligent Tutoring Systems (ITS) are computer-based instructional programs using artificial intelligence to provide personalized instruction and feedback to learners. According to VanLehn (2021), ITS replicates one-on-one human tutoring by adapting instruction to individual needs, monitoring progress, identifying knowledge gaps, and providing tailored support. The fundamental architecture comprises four key models: the domain model (containing expert knowledge), student model (tracking learner's knowledge state and misconceptions), pedagogical model (determining instructional strategies), and interface model (managing user interaction) (Walkington & Bernacki, 2020; Chrysafiadi & Virvou, 2022; Alkhatlan & Kalita, 2021).

Recent advancements in artificial intelligence and machine learning have enhanced ITS capabilities, enabling natural language dialogues, recognition of multiple solution strategies, step-by-step guidance, and adaptation based on affective states (Baidoo-Anu & Ansah, 2023). Feza (2020) demonstrated that technology-enhanced instruction improved South African students' number sense and problem-solving. In Nigeria, Abakpa and Agbo-Egwu (2020) found that computer-assisted instruction significantly improved mathematics achievement in Benue State. Okonkwo and Obielodan (2021) found video-based instruction improved achievement and attitudes in Lagos State. Adegoke (2021) found high mathematics anxiety levels in Oyo State, suggesting individualized approaches could reduce anxiety. Odili (2021) demonstrated that virtual manipulatives significantly improved algebra achievement in Rivers State.

Academic achievement refers to the extent learners have attained educational goals, typically measured through standardized tests or examinations (Owan et al., 2020). In Mathematics, this encompasses mastery of concepts, procedures, and problem-solving skills. Several factors influence mathematics achievement, including, cognitive factors (prior knowledge, spatial reasoning, working



memory, metacognitive skills), affective factors (mathematics anxiety, self-efficacy, attitudes), and environmental factors (instruction quality, learning resources, class size, home support) (Adesoji & Omoba, 2020; Mutlu, 2020; Okonkwo & Obielodan, 2021).

Numerous studies between 2020 and 2023 have investigated ITS effects on mathematics achievement. Ritter et al. (2020) conducted a randomized controlled trial across 73 U.S. schools with 2,850 students, showing significantly higher algebra test scores for ITS users with lower-performing students showing greatest gains. Fletcher (2020) noted that implementation quality, teacher support, and curriculum alignment significantly moderate ITS effectiveness. The challenges facing Nigerian mathematics education include inadequate foundational knowledge, procedural instruction emphasizing memorization over conceptual understanding, large class sizes limiting individualized attention, and limited access to manipulatives and technology (Abakpa & Agbo-Egwu, 2020; Odili, 2021). The abstract nature of mathematical concepts presents cognitive challenges that traditional instruction often fails to address through adequate scaffolding and multiple representations (Anthony & Walshaw, 2020).

Gender differences in mathematics achievement show complex, sometimes contradictory findings across contexts. While historical stereotypes associated mathematics with males (Gunderson et al., 2022), recent meta-analyses reveal that gender differences have narrowed considerably, though gaps persist in some contexts. In Nigeria, findings have been mixed, with some studies reporting male superiority attributed to cultural factors and traditional gender expectations (Ajai & Imoko, 2020). Technology-enhanced learning environments may reduce gender gaps by providing non-threatening, personalized experiences that reduce stereotype threat (Seo et al., 2021).

2.3 Critical Perspectives on ITS Research

While the body of evidence supporting ITS effectiveness is substantial, several limitations in the existing literature warrant acknowledgment. First, many ITS studies have been of relatively short duration (4-12 weeks), raising questions about long-term retention and transfer effects (Kulik & Fletcher, 2020). Second, most research has been conducted in well-resourced educational contexts with robust technological infrastructure, limiting generalizability to resource-constrained environments such as many African schools (Feza, 2020). Third, publication bias may inflate reported effect sizes, as studies showing null or negative results are less likely to be published. Finally, few studies have examined the mechanisms through which ITS affects learning, focusing instead on outcome comparisons without detailed process analysis.

These limitations underscore the need for rigorous, well-documented, longer-term studies in diverse contexts, including the Nigerian educational setting.

3. MATERIALS AND METHODS

3.1 Research Design

This study employed a quasi-experimental research design, specifically the pretest-posttest non-equivalent control group design, appropriate for educational research where random assignment of individual students is often not feasible (Creswell & Creswell, 2018).



The design is represented as:

Experimental Group: $O_1 \times O_2$

Control Group: $O_3 - O_4$

Where O_1 and O_3 represent pretest observations, X represents the treatment (Intelligent Tutoring Instructional Strategy), $(-)$ represents conventional teaching method, and O_2 and O_4 represent posttest observations. The use of intact classes reduced disruption while the pretest provided baseline data for statistical control through ANCOVA.

3.2 Population of the Study

The population comprised all Senior Secondary School 2 (SS2) Mathematics students in public secondary schools in Osun State, Nigeria. According to the Osun State Ministry of Education records for 2023/2024, there were approximately 28,450 SS2 students across 245 public secondary schools. SS2 students were selected because they have adequate foundational knowledge and are not yet preparing for external examinations.

3.3 Sample and Sampling Technique

The sample consisted of 240 SS2 Mathematics students from four purposively selected public secondary schools based on availability of computer laboratory facilities, stable electricity supply, willingness to participate, and comparable student characteristics. Two schools were randomly assigned to the experimental group (122 students: 64 males, 58 females) and two to the control group (118 students: 61 males, 57 females). Power analysis indicated this sample size provided 80% power to detect a medium effect size ($d = 0.5$) at $\alpha = 0.05$.

3.4 Research Instrument

The Mathematics Achievement Test (MAT), developed by the researcher, consisted of 50 multiple-choice items covering Quadratic Equations (13 items), Simultaneous Equations (12 items), Trigonometry (13 items), and Statistics (12 items). Items were distributed across Bloom's Taxonomy cognitive levels: Knowledge (18 items), Comprehension (16 items), Application (12 items), and Analysis (4 items). Each correct answer was awarded 2 marks, giving a maximum score of 100 marks.

3.5 Validation of Instrument

Face and content validity were established by three experts: two Mathematics education lecturers from Obafemi Awolowo University and one experienced SS2 Mathematics teacher. Based on their recommendations, items were modified for clarity, four items were removed for ambiguity, and six items were added to ensure adequate content coverage.

3.6 Reliability of Instrument

Reliability was determined through a pilot study with 40 SS2 Mathematics students from a similar school not included in the main study. The pilot study served three purposes: (1) to determine MAT reliability, (2) to refine system functionality and identify technical issues, and (3) to train research assistants in standardized administration procedures.



Based on pilot findings:

1. Three MAT items with poor discrimination indices (< 0.20) were revised for clarity
2. System response time was optimized by compressing image files
3. Hint sequencing for quadratic equation problems was adjusted based on common error patterns
4. Research assistant training protocols were refined to ensure standardization

Internal consistency reliability calculated using Kuder-Richardson formula 20 (KR-20) yielded a coefficient of 0.86, considered high and acceptable for educational research (Fraenkel et al., 2019).

3.7 Experimental Procedure

3.7.1 Development and Selection of Intelligent Tutoring System

An intelligent tutoring system called "MathTutor Pro" was adapted and customized for the Nigerian SS2 Mathematics curriculum. The original system, developed by EduTech Solutions Ltd., had been previously validated in South African secondary schools ($n = 450$ students across 6 schools) with demonstrated effectiveness (effect size $d = 0.52$) and high user satisfaction ratings.

For the Nigerian context, validation involved three phases:

1. **Content validation:** Three mathematics education experts and two experienced SS2 mathematics teachers reviewed all content for curriculum alignment, cultural appropriateness, language clarity, and mathematical accuracy. Agreement coefficient (Aiken's V) ranged from 0.87 to 0.94 across content domains.
2. **Technical validation:** The system underwent technical testing in Nigerian school conditions (variable electricity supply, moderate internet bandwidth) for four weeks in two schools not included in the main study, confirming functionality and stability.
3. **Pilot validation:** During the pilot study ($n = 40$), students' system usage data, error logs, and satisfaction surveys were analyzed. Based on feedback, minor adjustments were made to interface design, hint phrasing, and example complexity.

The customization process included:

1. Populating the domain model with Nigerian curriculum-aligned content covering Quadratic Equations, Simultaneous Equations, Trigonometry, and Statistics
2. Developing 450+ diagnostic and practice items reviewed by content experts
3. Creating culturally relevant word problems featuring Nigerian contexts, names, and currency
4. Programming adaptive pathways with decision rules based on mastery thresholds (80% accuracy)
5. Implementing a feedback system providing worked solutions with step-by-step explanations
6. Incorporating a student model tracking individual progress, error patterns, time-on-task, and hint usage

The system was accessible via web browsers with offline capability for downloaded modules, addressing potential internet connectivity issues.

3.7.2 Training of Research Assistants and Teachers

Four Mathematics teachers were trained to facilitate the study. Two experimental school teachers received two days intensive training on operating MathTutor Pro, monitoring progress through



dashboards, providing technical support, maintaining engagement without direct mathematical assistance, and understanding underlying pedagogical principles. Two control school teachers were oriented on study procedures and continued using conventional methods including lecture, chalkboard demonstrations, worked examples, practice exercises, and homework. Four graduate students in Mathematics Education were trained as research assistants.

3.7.3 Pretest Administration

One week before the intervention, the MAT was administered as a pretest under standardized conditions. Students were given 90 minutes to complete the test, with calculators permitted. Research assistants supervised to ensure standardization.

3.7.4 Intervention Phase

The intervention lasted eight weeks during the second term of 2023/2024, with both groups receiving instruction on the same topics for five 40-minute periods per week.

Experimental Group: Students used MathTutor Pro in computer laboratories, involving initial diagnostic assessment, adaptive content presentation, interactive learning modules with multiple representations, worked examples, practice problems with immediate feedback, adaptive scaffolding, dynamic visualizations, progress tracking, and remediation modules. Students worked individually at their own pace, with the system requiring demonstrated mastery (80% accuracy) before advancement. Teachers monitored progress and provided motivational support without directly teaching content.

Control Group: Students received traditional instruction including teacher exposition, chalkboard demonstrations, worked examples, question-and-answer sessions, practice exercises, homework assignments, and periodic tests. Teachers maintained regular pedagogical approaches covering the same topics in the same sequence without technology enhancement. Students received feedback according to normal schedules.

3.7.5 Implementation Fidelity

To ensure adherence to the experimental protocol and maintain intervention integrity, implementation fidelity was monitored through multiple mechanisms:

For the Experimental Group (ITIS):

1. **System logs:** MathTutor Pro automatically recorded student login times, time-on-task, modules completed, problems attempted, accuracy rates, and hint usage. Weekly reports were generated and reviewed by the research team.
2. **Classroom observations:** Research assistants conducted bi-weekly structured observations using a fidelity checklist documenting: (a) student engagement with the system (target: $\geq 90\%$ of students actively working), (b) teacher non-interference with mathematical content (target: zero instances of direct teaching), (c) technical functionality (target: $\geq 95\%$ of computers operational), and (d) adherence to session duration (target: 40 minutes \pm 5 minutes).
3. **Teacher logs:** Teachers maintained daily logs recording attendance, technical issues, and any deviations from protocol.
4. **Fidelity rate:** Overall fidelity averaged 94.3%, with 38 of 40 planned sessions (95%) completed as intended. Two sessions required extension due to internet connectivity issues but were completed within the same week.



For the Control Group (Conventional Method):

1. **Lesson observations:** Research assistants conducted bi-weekly observations documenting: (a) instructional methods used (lecture, demonstration, guided practice, etc.), (b) adherence to conventional approach (no use of computers or adaptive technology), (c) topic coverage aligned with experimental group, and (d) session duration.
2. **Teacher interviews:** Brief weekly interviews confirmed topics covered and methods used.
3. **Fidelity rate:** Overall fidelity averaged 96.8%, with all 40 planned sessions completed. One teacher occasionally incorporated brief small-group activities, which was deemed acceptable within the conventional methods framework.

Topic coverage alignment: Both groups covered identical topics in the same sequence, confirmed through weekly coordination meetings between experimental and control group teachers and the research team.

3.7.6 Posttest Administration

Immediately after the eight-week intervention, the MAT was administered as a posttest under the same standardized conditions. Using the same test ensured equivalence of measurement and allowed reliable comparison of gains, with the eight-week interval minimizing practice effects.

3.8 Method of Data Analysis

Data were analyzed using descriptive statistics (means and standard deviations) and inferential statistics. Analysis of Covariance (ANCOVA) tested hypotheses 1 and 3, with posttest scores as the dependent variable, instructional strategy and gender as independent variables, and pretest scores as the covariate. Independent samples t-test tested hypothesis 2, comparing male and female achievement within the experimental group. All hypotheses were tested at 0.05 significance level. ANCOVA assumptions were tested and confirmed before analysis. Data analysis was performed using SPSS version 26.

4. RESULTS

4.1 Demographic Characteristics of Participants

Table 1 presents the demographic distribution of participants across the experimental and control groups.

Table 1: Distribution of Participants by Group and Gender

Group	Male	Female	Total
Experimental (ITIS)	64 (52.5%)	58 (47.5%)	122 (50.8%)
Control (Conventional)	61 (51.7%)	57 (48.3%)	118 (49.2%)
Total	125 (52.1%)	115 (47.9%)	240 (100%)

The distribution shows relatively balanced representation across gender and groups, with the experimental group having 122 students and the control group having 118 students. Male students constituted 52.1% of the total sample while female students represented 47.9%.



4.2 Research Question One

What is the difference in the mean academic achievement scores of students taught Mathematics using Intelligent Tutoring Instructional Strategy and those taught using conventional teaching methods?

Table 2 presents the descriptive statistics for pretest and posttest scores by instructional strategy.

Table 2: Mean and Standard Deviation of Achievement Scores by Instructional Strategy

Group	Test	N	Mean	SD	Mean Gain
Experimental (ITIS)	Pretest	122	38.24	11.45	32.67
	Posttest	122	70.91	12.28	
Control (Conventional)	Pretest	118	37.85	11.62	16.34
	Posttest	118	54.19	13.56	

Table 2 shows that both groups had similar pretest mean scores (Experimental: $M = 38.24$, $SD = 11.45$; Control: $M = 37.85$, $SD = 11.62$), indicating initial equivalence in Mathematics achievement. However, posttest scores revealed substantial differences. The experimental group achieved a mean posttest score of 70.91 ($SD = 12.28$) with a mean gain of 32.67 points, while the control group achieved a mean posttest score of 54.19 ($SD = 13.56$) with a mean gain of 16.34 points. This suggests that students taught using Intelligent Tutoring Instructional Strategy achieved higher academic performance than those taught using conventional methods.

To directly test the difference in learning gains between groups, an independent samples t-test was conducted comparing the gain scores (posttest - pretest) of the experimental group ($M = 32.67$, $SD = 9.84$) and control group ($M = 16.34$, $SD = 8.92$). The difference was statistically significant, $t(238) = 13.25$, $p < 0.001$, Cohen's $d = 1.72$, representing a very large effect size. This confirms that students in the ITIS group demonstrated significantly greater learning gains than students in the conventional instruction group.

4.3 Research Question Two

What is the difference in the mean academic achievement scores of male and female students taught Mathematics using Intelligent Tutoring Instructional Strategy?

Table 3 presents the descriptive statistics for achievement scores by gender within the experimental group.

Table 3: Mean and Standard Deviation of Achievement Scores by Gender (Experimental Group)

Gender	Test	N	Mean	SD	Mean Gain
Male	Pretest	64	38.47	11.23	32.19
	Posttest	64	70.66	12.15	
Female	Pretest	58	37.98	11.74	33.19
	Posttest	58	71.17	12.46	



Table 3 reveals that within the experimental group, both male and female students had similar pretest scores (Male: $M = 38.47$, $SD = 11.23$; Female: $M = 37.98$, $SD = 11.74$). The posttest scores also showed minimal difference (Male: $M = 70.66$, $SD = 12.15$; Female: $M = 71.17$, $SD = 12.46$). The mean gains were comparable, with male students gaining 32.19 points and female students gaining 33.19 points. This suggests that both genders benefited similarly from the Intelligent Tutoring Instructional Strategy.

4.4 Research Question Three

What is the interaction effect of instructional strategy and gender on students' mean academic achievement scores in Mathematics?

Table 4 presents the mean achievement scores for the interaction of instructional strategy and gender.

Table 4: Mean Achievement Scores for Interaction of Instructional Strategy and Gender

Instructional Strategy	Gender	N	Pretest Mean (SD)	Posttest Mean (SD)
ITIS	Male	64	38.47 (11.23)	70.66 (12.15)
	Female	58	37.98 (11.74)	71.17 (12.46)
Conventional	Male	61	38.26 (11.45)	55.74 (13.28)
	Female	57	37.42 (11.84)	52.54 (13.82)

Table 4 shows that within the experimental group, female students slightly outperformed male students (mean difference of 0.51 points), while within the control group, male students outperformed female students by 3.20 points. This pattern suggests a possible interaction effect where the instructional strategy may differentially affect achievement based on gender, with ITIS potentially reducing or reversing the gender gap observed in conventional instruction.

4.5 Hypothesis One

H_{01} : There is no significant difference in the mean academic achievement scores of students taught Mathematics using Intelligent Tutoring Instructional Strategy and those taught using conventional teaching methods.

To test this hypothesis, Analysis of Covariance (ANCOVA) was conducted with posttest scores as the dependent variable, instructional strategy as the independent variable, and pretest scores as the covariate.

Before conducting ANCOVA, assumptions were tested:

1. **Independence of observations:** Confirmed through research design (different schools/classes)
2. **Normality:** Shapiro-Wilk test showed normal distribution of residuals ($W = 0.986$, $p = 0.118$)
3. **Homogeneity of variance:** Levene's test was not significant ($F = 1.87$, $p = 0.173$)
4. **Homogeneity of regression slopes:** Interaction between covariate and independent variable was not significant ($F = 0.64$, $p = 0.425$)
5. **Linear relationship:** Scatterplot confirmed linear relationship between pretest and posttest scores ($r = 0.64$)



Table 5 presents the ANCOVA results for the effect of instructional strategy on achievement.

Table 5: ANCOVA Summary for Effect of Instructional Strategy on Mathematics Achievement

Source	Sum of Squares	df	Mean Square	F	p-value	Partial η^2
Pretest (Covariate)	9,456.82	1	9,456.82	112.34	< 0.001	0.321
Instructional Strategy	14,182.56	1	14,182.56	168.45	< 0.001	0.415
Error	19,953.47	237	84.18			
Total	43,592.85	239				

Table 5 shows that after controlling for pretest scores, there was a statistically significant effect of instructional strategy on Mathematics achievement, $F(1, 237) = 168.45$, $p < 0.001$, partial $\eta^2 = 0.415$. The large effect size (partial $\eta^2 = 0.415$) indicates that instructional strategy accounted for approximately 41.5% of the variance in posttest scores after controlling for pretest scores. Therefore, the null hypothesis was rejected. Students taught using Intelligent Tutoring Instructional Strategy achieved significantly higher academic performance in Mathematics than those taught using conventional methods.

The adjusted means (controlling for pretest scores) were:

1. Experimental Group (ITIS): $M = 70.87$, $SE = 0.83$
2. Control Group (Conventional): $M = 54.23$, $SE = 0.85$

The mean difference of 16.64 points (on a 100-point scale) represents a substantial practical significance in addition to the statistical significance.

4.6 Hypothesis Two

H_{02} : There is no significant difference in the mean academic achievement scores of male and female students taught Mathematics using Intelligent Tutoring Instructional Strategy. An independent samples t-test was conducted to compare the posttest scores of male and female students in the experimental group. The Levene's test for equality of variances was not significant ($F = 0.38$, $p = 0.539$), indicating homogeneity of variance. Table 6 presents the t-test results.

Table 6: Independent Samples t-test for Gender Difference in Achievement (Experimental Group)

Gender	N	Mean	SD	Df	t	p-value	Cohen's d
Male	64	70.66	12.15	120	-0.231	0.818	0.042
Female	58	71.17	12.46				

Table 6 shows that there was no statistically significant difference in the posttest achievement scores of male ($M = 70.66$, $SD = 12.15$) and female ($M = 71.17$, $SD = 12.46$) students taught using ITIS, $t(120) = -0.231$, $p = 0.818$, Cohen's $d = 0.042$. The effect size was negligible. Therefore, the null hypothesis was not rejected. Both male and female students benefited equally from the Intelligent Tutoring Instructional Strategy in Mathematics.

4.7 Hypothesis Three

H_{03} : There is no significant interaction effect of instructional strategy and gender on students' academic achievement in Mathematics.



To test this hypothesis, a two-way Analysis of Covariance (ANCOVA) was conducted with posttest scores as the dependent variable, instructional strategy and gender as independent variables, pretest scores as the covariate, and the instructional strategy \times gender interaction term. Table 7 presents the results.

Table 7: Two-way ANCOVA Summary for Interaction Effect of Instructional Strategy and Gender

Source	Sum of Squares	Df	Mean Square	F	p-value	Partial η^2
Pretest (Covariate)	9,387.45	1	9,387.45	111.82	< 0.001	0.322
Instructional Strategy	14,156.32	1	14,156.32	168.64	< 0.001	0.418
Gender	124.67	1	124.67	1.48	0.224	0.006
Strategy \times Gender	246.85	1	246.85	2.94	0.088	0.012
Error	19,677.56	235	83.73			
Total	43,592.85	239				

Table 7 shows that the interaction effect of instructional strategy and gender on Mathematics achievement was not statistically significant at the conventional alpha level of 0.05, $F(1, 235) = 2.94$, $p = 0.088$, partial $\eta^2 = 0.012$. Therefore, the null hypothesis was not rejected. However, it is important to acknowledge that the p-value of 0.088 approaches the significance threshold and may indicate a trend worthy of further investigation with larger samples or longer intervention periods. The effect size was very small, suggesting that even if statistically significant with a larger sample, the practical magnitude of the interaction would be minimal.

The pattern underlying this near-significant interaction is theoretically meaningful (see Table 4). In the conventional instruction group, male students outperformed female students by 3.20 points (males: $M = 55.74$; females: $M = 52.54$), representing a 6.1% performance gap. In contrast, in the ITIS group, this pattern reversed, with female students slightly outperforming male students by 0.51 points (males: $M = 70.66$; females: $M = 71.17$), representing a 0.7% difference favoring females. This suggests that ITIS may reduce or eliminate gender disparities present in conventional instruction, a finding consistent with recent literature on technology-enhanced learning and gender equity (Gunderson et al., 2022; Seo et al., 2021).

We recommend that future research with larger samples and longer interventions explicitly examine this potential moderating effect of instructional strategy on gender differences. The table also reveals that the main effect of instructional strategy remained highly significant ($F = 168.64$, $p < 0.001$) while the main effect of gender was not significant ($F = 1.48$, $p = 0.224$). This indicates that instructional strategy was the primary factor influencing achievement, with no significant gender differences across both instructional approaches.



4.8 Additional Analysis

To further explore the patterns of achievement, Table 8 presents the distribution of students across achievement categories (based on Nigerian grading system) for both groups.

Table 8: Distribution of Students by Achievement Categories

Category	Score Range	Experimental Group	Control Group
Excellent	75-100	42 (34.4%)	8 (6.8%)
Very Good	70-74	36 (29.5%)	17 (14.4%)
Good	60-69	29 (23.8%)	35 (29.7%)
Credit	50-59	12 (9.8%)	34 (28.8%)
Pass	40-49	3 (2.5%)	18 (15.3%)
Fail	0-39	0 (0.0%)	6 (5.1%)
Total		122 (100%)	118 (100%)

Table 8 reveals that 63.9% of students in the experimental group achieved scores of 70 or above (Very Good to Excellent), compared to only 21.2% in the control group. Additionally, no student in the experimental group failed (scored below 40), while six students (5.1%) in the control group failed. This distribution further supports the effectiveness of ITIS in improving Mathematics achievement across all performance levels.

Table 9 presents achievement distributions by gender within each instructional strategy group.

Table 9: Distribution of Achievement Categories by Gender and Instructional Strategy

Achievement Level	ITIS Male	ITIS Female	Conventional Male	Conventional Female
Excellent (75-100)	21 (32.8%)	21 (36.2%)	5 (8.2%)	3 (5.3%)
Very Good (70-74)	19 (29.7%)	17 (29.3%)	10 (16.4%)	7 (12.3%)
Good (60-69)	16 (25.0%)	13 (22.4%)	19 (31.1%)	16 (28.1%)
Credit (50-59)	6 (9.4%)	6 (10.3%)	17 (27.9%)	17 (29.8%)
Pass (40-49)	2 (3.1%)	1 (1.7%)	9 (14.8%)	9 (15.8%)
Fail (0-39)	0 (0.0%)	0 (0.0%)	1 (1.6%)	5 (8.8%)
Total	64 (100%)	58 (100%)	61 (100%)	57 (100%)

Table 9 shows that within the ITIS group, achievement distributions were remarkably similar for male and female students, with both genders having approximately one-third of students in the Excellent category. In the conventional group, males showed slightly better performance, particularly with fewer failures among males (1.6%) compared to females (8.8%). This pattern provides additional support for the conclusion that ITIS promotes gender equity in mathematics achievement.

5. DISCUSSION

5.1 Effect of Intelligent Tutoring Instructional Strategy on Mathematics Achievement

Students taught using Intelligent Tutoring Instructional Strategy (ITIS) achieved significantly higher performance than those in conventional instruction, consistent with substantial research demonstrating ITS effectiveness (Ritter et al., 2020; VanLehn, 2021). This superior performance can be attributed to four key features:



First, Adaptive instruction calibrated content to each student's current understanding and knowledge gaps. Unlike conventional instruction with uniform pacing that leaves students with compounding deficits, the system provided targeted remediation before advancing, for example, addressing weak algebraic manipulation before introducing quadratic equations. Second, adaptive scaffolding provided detailed guidance when students struggled and faded support as competence increased, consistent with Zone of Proximal Development theory (Ritter et al., 2020). This balanced procedural fluency with conceptual understanding. Third, cognitive load management sequenced content carefully, used multiple representations, and adjusted difficulty progressively, consistent with Cognitive Load Theory (Kalyuga & Singh, 2021). Complex topics were broken into manageable sub-goals while building toward integrated competencies. Fourth, personalized pacing allowed each student necessary time on challenging concepts while moving quickly through mastered material, optimizing learning efficiency for all rather than pacing for the average student. The observed effect size (partial $\eta^2 = 0.415$, equivalent to Cohen's $d \approx 1.50$) is substantial. Kulik and Fletcher's (2016) meta-analysis of 50 ITS evaluations reported a median effect size of $d = 0.66$ (range: 0.05-1.05), placing our observed effect at the upper bound of this distribution. This suggests either particularly effective implementation, strong receptivity in the Nigerian context, or both. This finding extends previous Nigerian research by Abakpa and Agbo-Egwu (2020) and Odili (2021) by demonstrating adaptive intelligent tutoring effectiveness rather than general computer-assisted instruction. However, successful implementation requires attention to infrastructure (reliable computers, internet, and electricity), teacher preparation in facilitating technology-enhanced learning, and culturally appropriate content aligned with Nigerian curriculum.

5.2 Variability in Learning Outcomes

The relatively large standard deviations observed in both groups (experimental posttest SD = 12.28; control posttest SD = 13.56) indicate substantial individual differences in mathematics achievement even within instructional conditions. This variability is not uncommon in educational research and likely reflects multiple factors including prior knowledge differences, mathematics anxiety levels, motivation, home support, and general academic aptitude. Notably, the control group showed slightly greater variability than the experimental group, though this difference was not statistically significant. The marginally lower variability in the ITIS group may suggest that adaptive instruction provides more consistent support across diverse learners, reducing the spread of outcomes a pattern consistent with the theoretical foundation of adaptive learning (Vandewaetere et al., 2021). However, this interpretation should be considered tentative and warrants further investigation. The achievement distribution analysis (Table 8) provides additional insight, showing that while ITIS improved performance across all levels, individual differences persisted. This underscores that even highly effective instructional interventions operate within the context of individual learner characteristics. Future research should examine whether longer-term ITIS use further reduces variability by addressing cumulative knowledge gaps.

5.3 Gender Differences in Mathematics Achievement with Intelligent Tutoring Instructional Strategy

No significant gender difference emerged in mathematics achievement with ITIS; both genders achieved comparable posttest scores and similar learning gains. This aligns with recent research reporting no significant gender differences with intelligent tutoring systems (Seo et al., 2021; Gunderson et al., 2022), and is particularly important in the Nigerian context, where previous research sometimes reported disparities favoring males (Ajai & Imoko, 2020).



5.4 Interaction Effect of Instructional Strategy and Gender

No statistically significant interaction effect emerged, though the p-value (0.088) approached significance. However, the pattern is noteworthy: in the control group, male students outperformed females by 3.20 points, while in the experimental group, females slightly outperformed males by 0.51 points. This reversal suggests ITIS may reduce or eliminate gender gaps present in conventional instruction. This near-significant trend aligns with findings that adaptive systems eliminate traditional gender gaps (Gunderson et al., 2022) and provide particular affective benefits for female students (Mutlu, 2020).

5.5 Implications for Practice and Policy

1. **Curriculum integration.** Educational authorities should integrate adaptive learning technologies into mathematics curriculum, developing or acquiring culturally appropriate systems aligned with Nigerian curricula, particularly for topics where student performance has been weak.
2. **Teacher professional development.** Teachers need training to reconceptualize their roles from knowledge sources to learning facilitators, monitoring student progress through dashboards, identifying students needing support, and providing encouragement. Professional development must address both technical skills and pedagogical shifts.
3. **Infrastructure investment.** Effective implementation requires reliable computers/tablets, stable internet (or offline solutions), and consistent electricity. Government and school administrators must prioritize these investments, potentially through partnerships with technology companies, NGOs, or international development agencies.
4. **Gender equity initiatives.** The finding that intelligent tutoring promotes gender equity suggests strategic employment to increase female participation and success in STEM fields. Strategic implementation in girls' schools or contexts where gender gaps exist could promote more equitable outcomes.

6. CONCLUSION

This study investigated the effects of Intelligent Tutoring Instructional Strategy on academic achievement in Mathematics among senior secondary school students in Osun State, Nigeria. Based on the findings, the following conclusions are drawn:

- Intelligent Tutoring Instructional Strategy is significantly more effective than conventional teaching methods in improving students' academic achievement in Mathematics. Students taught using ITIS achieved substantially higher scores with a large effect size, demonstrating both statistical and practical significance. The mean gain of 32.67 points for ITIS students compared to 16.34 points for conventionally taught students represents approximately twice the raw score improvement. It is important to note that this comparison refers to raw score differences rather than standardized effect sizes; when controlling for pretest differences through ANCOVA, the partial η^2 of 0.415 indicates that instructional strategy accounted for approximately 41.5% of variance in posttest scores. Both metrics converge in demonstrating substantial practical significance of the ITIS intervention.



- Gender does not significantly influence academic achievement in Mathematics among students taught using Intelligent Tutoring Instructional Strategy. Both male and female students benefit equally from this technology-enhanced personalized learning approach, with nearly identical posttest scores and learning gains. There is no statistically significant interaction between instructional strategy and gender in determining Mathematics achievement, though patterns suggest that ITIS may reduce gender gaps present in conventional instruction. The effectiveness of ITIS is consistent for both male and female students.
- Intelligent Tutoring Instructional Strategy addresses several critical limitations of conventional mathematics teaching methods by providing adaptive instruction, immediate specific feedback, personalized pacing, worked examples with fading scaffolding, multiple representations, and mastery-based progression. The findings support the theoretical frameworks of Adaptive Learning Theory, Cognitive Load Theory, and Zone of Proximal Development Theory, demonstrating that intelligent tutoring systems operationalize key principles from these theories to enhance mathematics learning. Technology-enhanced personalized learning through intelligent tutoring systems is feasible and highly effective in the Nigerian secondary school context when adequate infrastructure, culturally appropriate content, and teacher support are provided. The high effect size observed in this study suggests that intelligent tutoring systems may be particularly effective in contexts where conventional instruction faces significant challenges such as large class sizes, limited individualized attention, and diverse student preparation levels.

7. RECOMMENDATIONS

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

7.1 Recommendations for Practice

1. The Federal Ministry of Education should develop national policies that support ITS integration including: (a) minimum infrastructure standards for secondary schools (computer-to-student ratios, internet bandwidth, power redundancy), (b) curriculum guidelines for blended learning with ITS, (c) data privacy and security standards for student learning analytics, (d) procurement frameworks for ITS content aligned with Nigerian curricula, and (e) funding mechanisms for schools in underserved areas.
2. Curriculum developers should incorporate intelligent tutoring systems into the Mathematics curriculum implementation guidelines, including recommendations for blended learning approaches and alignment with curriculum standards.
3. State Ministries of Education should provide funding for technological infrastructure like computers, internet connectivity, power sources, and technical support. Special intervention funds should support schools in underserved rural areas.

7.2 Recommendations for Further Research

1. Longitudinal studies should examine long-term effects on mathematics achievement, knowledge retention, transfer to advanced courses, attitudes toward mathematics, and STEM career pursuit.



2. Research should explore optimal integration of intelligent tutoring systems with traditional instruction, investigating different blended learning models to maximize complementary strengths.

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