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EFFECT OF INTELLIGENT TUTORING SYSTEMS ON STUDENTS' ACADEMIC PERFORMANCE IN MATHEMATICS AMONG SECONDARY SCHOOL STUDENTS IN IMO STATE

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Abstract

This study examines the impact of the Intelligent Tutoring System on the academic performance of secondary school students in mathematics in Imo State, Nigeria. This study adopted a quasi-experimental research design using a pre-test, and post-test control group approach. The study population comprises all senior secondary school students in SS2 (Grade 11) in public secondary schools in Imo State. A sample of 120 students was selected from three public secondary schools in Imo State through a multi-stage sampling technique. Simple random sampling was used to select four schools. The Mathematics Performance Test (MPT), validated by experts and tested for reliability, was used to collect data before and after the intervention. The reliability of the instrument was determined using Kuder-Richardson Formula 20 (KR-20) with a reliability coefficient of 0.87 considered acceptable. Data were analyzed using mean, standard deviation, T-test, and Analysis of variance (ANOVA) was used to test the hypotheses at 0.05 level of significance. The findings reveal that students taught with ITS performed significantly better in mathematics than those taught through traditional methods. Moreover, there is a significant difference in the performance of students exposed to pre-test and post-test using ITS. The study, therefore, recommends that the Ministry of Education and school administrators in Imo State should integrate ITS

tools into the mathematics curriculum to help improve performance and bridge individual learning gaps.

Keywords: Intelligent Tutoring Systems, Academic performance, and mathematics.

Introduction

The use of intelligent tutoring systems (ITS) in education focuses on the potential to improve academic achievement for students, a mathematics that is often classified as particularly difficult. Intelligent tutorial systems represent powerful innovation in education, especially in contexts where personalized lessons are lacking due to lack of class size and inadequate teacher support. Mathematics can greatly improve learners' understanding, performance and autonomy (Nkadi and Obasi ,2022). Intelligent Tutoring System (ITS) is a computer - assisted education system that provides a personalized adaptive learning experience. They aim to replicate the effectiveness of one-to-one tutoring lessons by using artificial intelligence (AI) to respond in real-time. He continuously evaluates learners' knowledge, skills and misconceptions to adapt their lessons accordingly. An intelligent tutorial system is a computer-aided learning environment that uses artificial intelligence technology to provide learners with immediate and taker instructions or feedback. Ma *et al* (2014) conducted a meta-analysis of 107 studies and found that students who received an average effect size of 0.66 on average performed better on average. The authors concluded that it is particularly effective in mathematics due to adaptive skills and real-time feedback. Vanlehn (2011) compared the effectiveness of human tutoring, its traditional and traditional lessons. His findings showed that it was just as effective as human tutoring and far more effective than traditional classroom lessons. This study highlighted that it can simulate the benefits of individual learning, which are often missing in traditional settings. They aim to mimic discussion patterns and

problematic human expert solution strategies, and to give students personalized lessons and feedback. Cognitive tutors use models of human knowledge to predict student knowledge status and adapt lessons accordingly. Cognitive tutors guide students to complex problem-solving tasks on topics such as mathematics by providing step-by-step support, information and immediate feedback. In contrast to traditional drill-based software, cognitive tutors allow students to study a variety of solutions and intervene when needed. This promotes deep learning and conceptual understanding. Koedinger and Aleven (2007) emphasized that cognitive tutors support learning and support learning with robust feedback and scaffolding that adapts to the learner's pace and style. These are especially useful for students not only remembering procedures, but also developing problem solving skills. Cognitive tutors adapt to the pace and level of knowledge of all learners. They provide scaffolding and hints as students fight against what contributes to filling the learning gap between different learners (Pane et al., 2014).

Nye *et al* (2014) Like humans, it's like personal instruction by asking questions, explaining, providing information, and dealing with students in their own words. They build on Socrates' theories about education, constructivism, and cognitive apprentice training, highlighting learning through guided research and conversation. One of the most well-known dialog-based tutors is from Grasser et al. (2005). Auto Tutor attracts students with natural language talks on complex topics such as physics and computer power. The system recognizes students become confused, bored, and resolved, and adapts the answer to encourage learning. Grassler *et al*, (2005) have been shown to generate learning benefits that correspond to or exceed traditional tutoring. Especially when promoting understanding in place of monuments. These systems use artificial intelligence to

model both domestic knowledge and discourse strategies required for effective individualized instruction.

Cognitive-tutor is a type of Intelligent Tutoring System (ITS) designed to mimic the way human tutors teach students, by providing personalized instruction that adapts to the learner" space, needs, and problem-solving strategy. Koedinger and Corbett (2006) opined that a cognitive tutor is an intelligent tutoring system that uses a cognitive model of problem-solving to guide instruction and provide tailored feedback to students in real-time.

Dialogue-based tutors are a category of Intelligent Tutoring Systems (ITS) that use natural language conversation in the form of written or spoken dialogue to teach and support learners. These tutors are designed to stimulate human-human tutorial dialogue, enabling a more interactive, responsive, and engaging learning experience. Graesser *et al*, (2005) opined that Dialogue-based tutors are intelligent systems that engage students in natural-language dialogue, encouraging active knowledge construction through conversation, questioning, and explanation. Dialogue-based tutor conversational interfaces have been shown to enhance student motivation and commitment, especially for learners who have to deal with traditional lessons (D'Mello & Graesser, 2012). Dialogue-based ITS provides scaffolding feedback tailored to the learner's current understanding. This makes it effective for treatment measures and students with different levels of mathematics knowledge, as is common in Nigerian secondary schools (Vanlehn, 20011). In this approach, teachers provide content through lectures, demonstrations, and textbook-based learning, but students are expected to listen, take notes, and give truth sincerely. Evaluations often focus on exams and testing rather than ongoing feedback. In mathematics education, traditional methods usually include learning, solving on-board exercises and repetitive practices with limited interactions

between students and research. Although it has been the dominant teaching method for decades, critics argued that it does not properly deal with differences in individual learning or promote critical thinking and the ability to solve problems.

The conventional method of teaching refers to the traditional teacher-centered approach where the teacher is the primary source of knowledge, and students are passive recipients (Obanya,2004). This method typically involves lecturing, note-taking, rote memorization, and limited student interaction or practical engagement. Ibe and Nwosu (2003) opined that the conventional method is the common teacher-dominated instructional approach where the teacher transmits factual knowledge to learners, who are expected to listen, take notes, and reproduce the knowledge during assessments. Eggen and Kauchak (2012) said that traditional lessons emphasize the transfer of information from teachers to students. Covering large amounts of materials in a limited time is often effective, but may not support deep understanding or long-term storage. Afolabi andAkinbobola (2009) found that traditional methods help maintain discipline and structure, but may not meet the needs of different learners or support contemporary educational goals such as autonomy, creativity, and collaboration among learners.

Statement of the Problem

Mathematics remains one of the most challenging subjects for secondary school students, particularly in Nigeria, where poor academic performance has persisted. According to Okafor & Obi (2021) found that over 60% of sampled secondary students in South-East Nigeria scored below average in mathematics achievement tests. Moreover, Onyeka (2020) found significant underperformance in Imo State rural schools due to teacher shortages and inadequate instructional materials in various reforms. Traditional instructional methods often adopt a one-size-fits-all approach, which fails to meet the diverse learning needs and paces of

students. This has led to widespread disinterest, anxiety, and underachievement in mathematics. In recent years, Intelligent Tutoring Systems (ITS) have emerged globally as innovative educational tools capable of providing personalized, adaptive, and interactive instruction. These systems have been shown to stimulate the benefits of one-on-one human tutoring by adapting content delivery based on individual learners"s strengths and weaknesses. However, in the Nigerian context and specifically among secondary school students in Imo State, there is limited research and practical implementation of ITS in mathematics education. Despite the proven potential of ITS in improving academic outcomes, questions remain regarding its effectiveness, accessibility, and relevance in under-resourced educational environments. There is a pressing need to empirically investigate whether the adoption of ITS can significantly improve students' academic performance in mathematics compared to traditional teaching methods. Therefore, this study seeks to examine the effect of Intelligent Tutoring Systems on the academic performance of secondary school students in mathematics

Purpose of the Study

1. Determine the Cognitive tutors on students' academic performance in mathematics among secondary school students.
2. Determine the Dialogue -based -tutors on students' academic performance in mathematics among secondary school students.
3. Differentiate the difference in academic performance in mathematics between students taught using intelligent tutoring systems and those taught using conventional methods in secondary school schools

Research Questions

1. What are the cognitive tutors on students' academic performance in mathematics among secondary school students?

2. What are Dialogue-based tutors on students' academic performance in mathematics among secondary school students?
3. What is the difference in academic performance in mathematics between students taught using intelligent tutoring systems and those taught using conventional methods in secondary school students?

Hypotheses

1. There is no significant difference in the mean of cognitive tutors on students' academic performance in mathematics among secondary school students
2. There is no significant difference in the mean of Dialogue -based -tutors on students' academic performance in mathematics among secondary school students.
3. There is no significant difference in academic performance in mathematics between students taught using intelligent tutoring systems and those taught using conventional methods in secondary school schools.

Methodology

This study adopted a quasi-experimental research design using a pre-test, and post-test control group approach. Three research questions and three hypotheses. The study population comprises all senior secondary school students in SS2 (Grade 11) in public secondary schools in Imo State. A sample of 120 students was selected from four public secondary schools in Imo State through a multi-stage sampling technique. A simple random sampling technique was used to select three schools public schools. A Mathematics Performance Test (MPT), validated by experts and tested for reliability, was used to collect data before and after the intervention. The reliability of the instrument was determined using Kuder-Richardson Formula 20 (KR-20) with a reliability coefficient of 0.87 considered acceptable. Data were analyzed using mean, standard deviation, T-test, and

Analysis of variance (ANOVA) was used to test the hypotheses at 0.05 level of significance.

Result

Research Question One: What are the cognitive-tutors on students' academic performance in mathematics among secondary school students?

Table 1: Mean and Standard Deviation of pretest and post-test (Cognitive-tutors)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pretest	52.6500	40	7.10561	1.12350
	Postest	75.9250	40	8.60348	1.36033

The cognitive-tutors group's mean score and standard deviation were for pretest 52.65 and 7.12 respectively, while the post test group had a mean score of 75.92 and a standard deviation of 8.60. The result indicated that the students in post test perform brilliantly than those in pretest.

Research Question Two: What are Dialogue-based tutors on academic performance in mathematics among secondary school students?

Table 2: Mean and Standard Deviation of pretest and post-test (Dialogue- based tutors)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pretest	50.8500	40	8.44150	1.33472
	Postest	75.7000	40	10.14055	1.60336

The Dialogue-based tutors group's mean score and standard deviation were for pre-test 50.85 and 8.44 respectively, while the post-test group had a mean score of 75.70 and a standard deviation of 10.14. The result indicated that the students in the post-test performed more brilliantly than those in the pretest.

Research Question Three: What is the difference in academic performance in mathematics between students taught using intelligent tutoring systems and those taught using conventional methods in secondary school schools?

Table 3: Mean scores and standard deviation of male and female exposed to experimental and traditional assessment Groups.

Groups	Gender	N	Mean	S.D	Standard Error Mean
Cognitive-tutors	**Pretest**	**40**	52.6500	7.10561	**1.12350**
	Posttest	**40**	75.9250	8.60348	**1.36033**
Dialogue -based tutors	**Pretest**	**40**	50.8500	8.44150	**1.33472**
	Posttest	**40**	75.7000	10.14055	**1.60336**
Conventional method	**Pretest**	**40**	40.6500	6.65467	**1.05220**
	Posttest	**40**	55.1000	8.23314	**1.30177**

The results in Table 3, indicated that the mean for the pretest of Cognitive -tutors was 52.6500 (SD=7.10561), while the mean for the Post-test was 75.9250 (SD=8.60348) while the mean for the pretest of Dialogue-based tutors was 50.8500 (SD=8.44150), while the mean for post-test was 75.7000 (SD=10.14055). Whereas, the mean for the pretest of the conventional method was 40.6500 (SD=6.65467), while the mean for the post-test was 55.1000 (SD =8.23314). This implies therefore that the mean performance of students in cognitive-tutor groups was higher than the mean performance of students in Dialogue-based tutor groups and vice versa.

Hypothesis One: There is no significant difference in the cognitive tutors on students' academic performance in mathematics among secondary school students

Table 4:T-test Analysis of pretest and post-test (Cognitive-tutors)

Group	N	Mean	S.D	DF	T-test	p-value	Decision
Pretest	40	52.65	7.12	39	11.80	0.00	Significant
Post test	40	75.93	8.60				

The result in Table 4 shows the t-value (11.80) was obtained and a probability value is 0.00. The probability value of 0.00 was compared with 0.05

and it was found to be less than 0.05 (p <.05). Hence, the null hypothesis is rejected. This indicates that there is a significant disparity between the mean scores of students exposed to pre-test and post-test on the cognitive tutors on students' academic performance in mathematics.

Hypotheses Two: There is no significant Dialogue -based tutors on students' academic performance in mathematics among secondary school students

Table 4: T-test Analysis of pretest and post-test (Dialogue- based tutors)

Group	N	Mean	S.D	DF	T-test	p-value	Decision
Pretest	40	50.85	8.44	39	11.09	0.00	Significant
Post test	40	75.70	10.14				

The result in Table 5 shows the t-value (11.09) was obtained and a probability value is 0.00. The probability value of 0.00 was compared with 0.05 and it was found to be less than 0.05 (p <.05). Hence, the null hypothesis is rejected. This indicates that there is a significant disparity between the mean scores of students exposed to pre-test and post-test on the Dialogue-based tutors on students' academic performance in mathematics.

Hypotheses Three: There is no significant difference in academic performance in mathematics between students taught using intelligent tutoring systems and those taught using conventional methods in secondary school schools

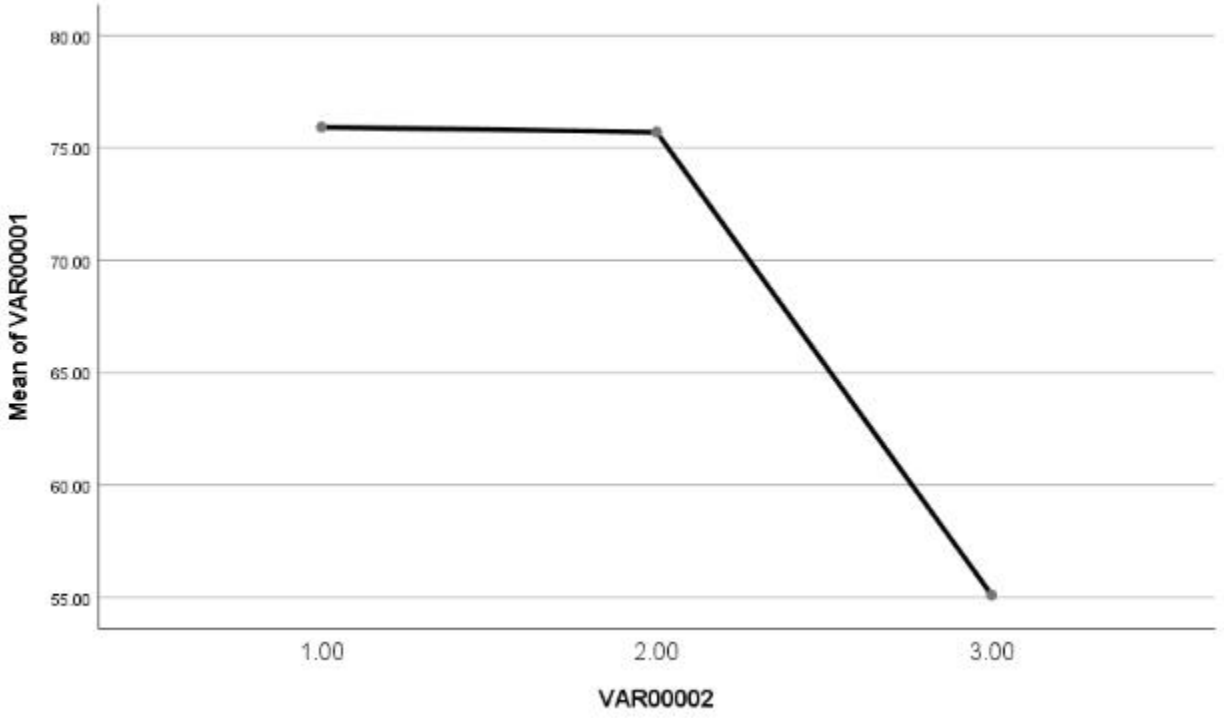
ANOVA

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	11441.217	2	5720.608	70.153	.000
Within Groups	9540.775	117	81.545		
Total	20981.992	119			

Table 6 shows the difference between the three groups exposed to intelligent tutoring systems and those exposed to conventional methods. F -value (70.15). The p-value (0.00) which is less than 0.05.Hence null hypothesis was retained at 0.05

alpha levels. This implies there is a statistically significant difference in mathematics academic performance among the three methods. Those taught with intelligent tutoring systems performed differently from those taught with conventional.

Mean Plots



The plot shows the average mathematics scores of students taught using three different methods. The conventional mean score is 55.10,the Cognitive tutor's mean score is 75.92 whereas the Dialogue-based tutor's mean score is 75.70. From the result it shows that Cognitive tutor has the highest score, suggesting they are the most effective among the three, Dialogue-based tutors performed significantly better than the conventional method. The convention method produced the lowest average performance. The upward slope in the plot indicates a positive effect of technology-enhanced methods (Cognitive and Dialogue-based) on academic performance in mathematics.

Discussion of Findings

The findings of this study revealed that the use of cognitive tutors significantly improved students' academic performance in mathematics compared to traditional instructional methods. Students exposed to cognitive tutor-based instruction demonstrated higher levels of problem-solving skills, conceptual understanding, and retention of mathematical procedures. The findings of this study align with Pane *et al* (2014) who suggest that the integration of intelligent tutoring systems like the cognitive tutor into the mathematics curriculum can address learning gaps, especially among low-performing students. The tutor" 's scaffolding features allowed for just-in-time assistance, reducing cognitive overload and enhancing learning efficiency.

The findings of the study indicated that dialogue-based tutors significantly enhance students' academic performance in mathematics. Students who interacted with dialogue-based tutoring systems outperformed their counterparts who received conventional instruction, particularly in areas of mathematical reasoning, problem-solving, and conceptual understanding. The findings of the study support Graesser *et al* (2005) who reported that Auto Tutor, a well-known dialogue-based intelligent tutoring system, was effective in promoting deep learning through natural language dialogue. This system engages students in a mixed-initiative conversation that mimics human tutoring, enabling learners to articulate their reasoning, receive immediate feedback, and correct misconceptions in real time. The findings are in line with Chi *et al* (2001) who found that tutorial dialogue promotes self-explanation, which is strongly correlated with improved mathematical understanding. The current study observed that students who used dialogue-based tutors were more likely to explain their thought processes aloud. Leading to better comprehension and retention of mathematical concepts.

The findings of this study indicate a significant difference in academic performance between secondary school students taught mathematics using the Intelligent Tutoring System (ITS) and those taught using the conventional (traditional) method. Students who learned through ITS demonstrated higher achievement scores, better conceptual understanding, and improved problem-solving skills compared to those taught using lecture-based or chalk-and-talk methods. The findings of the study align with the results of VanLehn (2011), who conducted a meta-analysis and concluded that students who received instruction through ITS performed as well as or better than those tutored by human teachers, and significantly better than students taught through traditional methods. The structured feedback, personalized pacing, and adaptive learning paths in ITS contributed to this improvement. However, in contrast, students in the conventional group often relied on memorization and passive learning, which limited their ability to engage deeply with mathematical concepts. As a result, their performance was generally lower. The findings are in line with Melesse and Belay (2022) who argued that traditional instructional methods often do not accommodate the diverse needs of learners, potentially leading to disengagement and lower academic performance. Adopting differentiated instruction and culturally responsive teaching practices is crucial for fostering an inclusive educational environment that supports all students.

Conclusion

The study concludes that the use of Intelligent Tutoring Systems (ITS) significantly enhances the academic performance of secondary school students in mathematics. Students who were taught using ITS demonstrated greater improvement in conceptual understanding, problem-solving skills, and overall achievement scores compared to those taught through traditional methods. The

adaptive nature of ITS -providing individualized feedback, immediate correction, and self-paced learning addresses the diverse learning needs often unmet in conventional classrooms.

Recommendations

1. There is a need for adequate teacher training and infrastructural support for effective implementation.
2. The Ministry of Education and school administrators in Imo State should integrate ITS tools into the mathematics curriculum and help improve performance and bridge individual learning gaps.
3. Schools should establish mechanisms for tracking student performance and evaluating the effectiveness of ITS in real classroom settings, to ensure sustained academic improvement and inform policy decisions.

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