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Effect of Intelligent Tutoring System on Secondary School Students' Academic Achievement in Biology in Esan West, Edo State

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Abstract

Within the domain of educational biology, despite the recognized societal importance of biological knowledge, student achievement in this discipline has persistently underperformed. The present study was on the effect of intelligent tutoring system on secondary school students' academic achievement in Biology in Edo state. The study adopted a quasi-experimental research design, specifically the non-randomized pretest-posttest control group design. The population of the study comprised 1,833 senior secondary school II students from twelve public secondary schools, while a sample of 88 students (52 males and 36 females) drawn from two intact classes was used for the study. The instrument used for data collection was Biology Achievement Test (BAT). adopted from WAEC past questions, with a reliability coefficient of 0.82 obtained using the Kuder Richardson (K-21) formula. Two hypotheses were formulated and tested at a 0.05 level of significance. The data collected from the respondents were analysed using mean and standard deviation for research question one and two and Analysis of Covariance (ANCOVA) was used to test the hypotheses one and two formulated for the study. The findings revealed that students taught Biology using the Intelligent Tutoring System achieved higher post-test mean scores of 75.73 than those taught using the conventional teaching method was 69.12. The study further revealed that there was a significant effect of instructional strategies on students' academic achievement in Biology, $P < 0.05$ However, no significant difference was found in the academic achievement of male and female students exposed to the Intelligent Tutoring System. Based on the finding, Intelligent Tutoring System is an effective instructional strategy for improving students' academic achievement in Biology regardless of the gender. It was therefore recommended that Biology teachers should integrate Intelligent Tutoring Systems into classroom instruction to enhance students' academic achievement and improve understanding of difficult Biology concepts.

Keywords: Academic achievement, Artificial intelligence, Intelligent Tutoring Systems, Secondary school Biology, Science education

INTRODUCTION

The Nigerian educational system could be presently experiencing a notable transformation driven by the incorporation of Artificial Intelligence within its instructional methodologies. Nigeria employs a 9-3-4 educational framework designed to deliver uninterrupted foundational education and equip students with skills for gainful employment. This system comprises 9 years of basic education, encompassing both lower and upper basic levels (junior secondary education), followed by 3 years of senior secondary education where students can concentrate on disciplines including Arts, Commerce/Social Sciences, and Pure Sciences, culminating in 4 years of tertiary education.

Science education, situated within the discipline of science pedagogy, functions as a fundamental catalyst for technological advancement. It encompasses a systematically

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organized corpus of knowledge that emphasizes scientific concepts and technological content. This academic and practical field focuses on the methodologies of teaching, learning, and evaluating scientific knowledge, processes, and the nature of science itself (Obialor, 2018). A distinctive feature of science education is its role in cultivating critical thinking and problem-solving skills essential for interpreting ethical issues and scientifically-based assertions (Greenfield et al., 2024). In the Nigerian context, the goals of science education include: (1) equipping students with the observational and exploratory skills necessary to engage with their environment, (2) enabling them to elucidate basic natural phenomena, (3) fostering a scientific attitude characterized by curiosity and critical analysis, and (4) applying acquired scientific skills and knowledge to address everyday environmental challenges (Madukwe, 2018). At the senior secondary school level in Nigeria, science education primarily comprises three core disciplines: physics, chemistry, and biology

Biology, fundamentally defined as the study of life, constitutes a core scientific discipline taught at the secondary education level aimed at providing students with a comprehensive and integrative understanding of key biological concepts, principles, theories, and laws (Bello et al., 2020). As a branch of natural science, biology investigates the origin of living organisms, their interactions with one another, and their relationships with the environment (Asuzu & Okoli, 2019). The discipline encompasses the study of living entities including plants and animals, both vertebrates and invertebrates focusing on their anatomical structures, biochemical processes, molecular interactions, physiological functions, and developmental biology (Adam et al., 2022). The scope of biology is extensive, ranging from detailed cellular biochemical activities to macro-level environmental phenomena such as ecosystems and global climate change. Central to biology's pedagogical objectives are elucidating fundamental life processes such as structure, function, evolution, growth, reproduction, and ecological interactions. Furthermore, the instructional goals of biology education involve equipping students with foundational biological knowledge, fostering scientific competencies including observation, experimentation, and critical analysis, and cultivating an appreciation of biodiversity (N.P.E., 2013). In contemporary society, biology holds critical significance within the secondary school curriculum designed to tackle societal issues, with the effectiveness of its educational impact heavily influenced by the teaching methodologies employed. Notably, in Nigerian secondary schools, the predominant instructional approach remains the lecture (conventional) teaching method.

In the domain of educational pedagogy, traditional instructional methods are characterized by a teacher-centered paradigm wherein educators serve as the primary purveyors of knowledge, and students assume a passive role predominantly as knowledge recipients (Perse, 2017). This pedagogical model encompasses didactic techniques such as lecturing, conceptual explanation by instructors, utilization of textbooks and chalkboards, alongside strategies of memorization and repetitive practice. Critically, this approach often omits active learning methodologies, which has been associated with diminished student motivation and suboptimal academic outcomes (Adeika et al., 2024). Within secondary biology education, learners frequently perceive the subject as inherently challenging, particularly grappling with abstract and complex concepts like the cell cycle and biochemical pathways, which necessitate novel and engaging instructional strategies to facilitate understanding (Aghasafari, 2023). Furthermore, topics such as DNA transcription prove difficult to assimilate via lecture method of teaching (Liang et al., 2023; Norizan et al., 2025). This difficulty largely stems from a predominant emphasis on rote memorization of abstract biological theories within existing curricula, resulting in students' limited exposure to and adaptability with emerging technological tools pertinent to biology education. Consequently, these challenges underscore an imperative to realign pedagogical practices to better accommodate learners' educational requirements and enhance academic performance in biology through the integration of advanced educational technologies, particularly artificial intelligence (AI).

Within the educational research domain, gender has been identified as a factor influencing student academic outcomes, alongside pedagogical approaches. Gender encompasses a broad spectrum of attributes, including both physical and biological

characteristics that distinguish males from females (Okeke, 2020). Extending beyond mere biological differences, gender also pertains to the societal roles, identities, limitations, and requirements attributed to males and females (Omotosho, 2019). Empirical investigations have yielded mixed findings; certain studies report no statistically significant differences in average academic performance between male and female students (Oludipe, 2019; Adigun, 2019; Gongden & Gongden, 2019). Conversely, other scholars have documented significant performance disparities between male and female students (Dorathy, 2015; Iloputaife, 2016), within educational technology.

In educational technology and biology education, the integration of artificial intelligence (AI) is imperative due to its capacity to enhance instructional methodologies and facilitate the acquisition of skills essential for navigating a rapidly evolving, technology-centric environment. AI technologies empower educators to develop more innovative and contextually pertinent educational content, thereby enabling personalized learning experiences that align with individual learners' cognitive preferences (Hidayat et al., 2024). AI-driven applications, including adaptive learning platforms, language acquisition tools, virtual instructional aides, real-time analytical dashboards for performance assessment, automated grading systems, and intelligent tutoring systems, play a pivotal role in advancing pedagogical approaches and evaluative techniques, ultimately contributing to the creation of more effective classroom environments (Almasri, 2024; Heeg & Avraamidou, 2023). Among these advancements, Intelligent Tutoring Systems (ITS) represent the most groundbreaking innovation within the field (Obermeier, 2024).

Intelligent Tutoring Systems (ITS) constitute a computational educational technology designed to deliver individualized instruction and immediate formative feedback akin to human tutoring. These systems mark a substantial advancement over conventional computer-assisted instruction by integrating sophisticated methodologies from machine learning, natural language processing, and cognitive modeling (Alenezi, 2023). Functioning as adaptive educational instruments, ITS tailor their pedagogical strategies to accommodate individual learners' unique pacing and cognitive styles, presenting customized explanations and practice exercises that collectively foster interactive learning environments. Within the domain of science education, particularly biology and physics, ITS have been effectively utilized to promote conceptual understanding and skill acquisition, thereby improving educational outcomes (Heeg & Avraamidou, 2023). Specifically, in biology instruction, ITS can enhance learning processes by furnishing personalized, scaffolded feedback and delivering content adapted to students' cognitive profiles. This individualized approach proves especially beneficial for complex subjects such as cell biology, where ITS can deconstruct multifaceted concepts through iterative scaffolding until mastery is achieved (Gunawan et al., 2021; Naya-Forcano et al., 2024). Moreover, ITS serve as valuable tools within biological education by providing adaptive feedback mechanisms and interactive supports that clarify intricate biological models and processes (Lawal et al., 2025).

Within the domain of educational biology, despite the recognized societal importance of biological knowledge, student achievement in this discipline has persistently underperformed. Empirical research conducted over several years has consistently demonstrated suboptimal academic outcomes among students studying biology (Akande et al., 2018; Effiong & Igiri, 2015; Joda, 2019; Olugbuye, 2017). Notably, student performance in biology during external examinations has exhibited marked inconsistency, with the proportion of students attaining credit-level passes remaining below 40% from 2019-2024 (Iyabo & Olajumoke, 2025). These trends underscore a continuing deficiency in academic success within the subject (Adolphus, 2018). Scholarly investigations have identified multiple contributing factors to this pervasive underperformance, including insufficient laboratory infrastructure, a scarcity of instructional resources, and the employment of suboptimal pedagogical strategies (Nwuba & Osuafor, 2021; Sambo, 2022; Ufommadu & Okoli, 2019).

Eryılmaz and Adabashi (2020) conducted an empirical investigation within the field of educational technology focused on the development of an Intelligent Tutoring System (ITS) employing Bayesian Networks and fuzzy logic to enhance higher education students'

academic achievement. Findings indicated that learners utilizing the FB-ITS exhibited statistically significant improvements in academic performance compared to peers engaging with the other ITS variants and the traditional e-learning system.

In a recent quasi-experimental investigation by Rababah (2023) examining the influence of an Intelligent Tutoring System (ITS) on the academic development and achievement of Jordanian students learning English as a Foreign Language (EFL) Findings revealed that students exposed to the ITS instructional approach demonstrated statistically significant improvements in language acquisition and academic performance. Notably, the experimental group outperformed the control group on post-intervention assessments in grammar, vocabulary, and reading comprehension measures.

In an investigation carried out by Villegas. et al. (2025) on adaptive intelligent tutoring systems for STEM education: analysis of the learning impact and effectiveness of personalized feedback. The findings revealed a significant improvement in several key metrics. The experimental group achieved an average precision of 85% in programming and 78% in mathematics, significantly outperforming the control group.

Schaaf, Rolfes, Nagy, and Heinze (2026) conducted a longitudinal empirical investigation within the field of educational technology to assess how the frequency of intelligent tutoring system (ITS) usage influences mathematics achievement among secondary education students. These findings suggest that mere usage frequency of ITS does not inherently translate to enhanced mathematics learning outcomes.

In a recent empirical investigation conducted by Hassan, Usman, Bala, Mannir, and Karfe (2023), the impact of a web-based intelligent tutoring system on students' academic achievement and engagement in technical drawing was explored within the context of Nigeria. The empirical results substantiate that web-based intelligent tutoring interventions significantly enhance both academic performance and interest levels in technical drawing compared to conventional instructional methodologies.

Shih, et al. (2023) also carried out a similar study on mathematics intelligent tutoring system for learning multiplication and division of fractions based on diagnostic teaching. The results of the study showed that the experimental group using the math ITS significantly outperformed the control group.

A study was carried out by Liu, Zhang and Jia (2024) on the design of guiding and adaptive prompts for Intelligent tutoring systems and Its effect on students' mathematics learning. The findings indicated that although the experimental group scored lower than the control group in the pretest, they scored higher in the posttest and spent less completion time. The drilled problems and the prompts provided to the experimental group students were personalized. It was concluded that the design principles for guiding and adaptive prompts in the ITS can provide personalized guidance and support for students, thus effectively improve their performance.

Although substantial evidence supports the educational benefits of this artificial intelligence tool, empirical research regarding its application in biology education within Esan West Central, Edo State, Nigeria remains insufficient. This study investigates the approaches and effects of technology integration aimed at fostering inclusive and personalized learning experiences in biology, focusing specifically on the deployment of intelligent tutoring systems (ITS) in the biology classroom. Furthermore, the research evaluates the influence of ITS on students' academic achievement in the subject of biology.

This study is structured around the following research questions: (1) What is the statistical difference in Biology achievement between students taught with ITS and those taught with conventional method? (2) What is the average achievement score of secondary school students taught biology utilizing both ITS and conventional instructional methods? Correspondingly, the study posits the following hypotheses: (1) There is no statistically significant difference in Biology achievement between students taught with ITS and those taught with conventional methods". (2) There is no statistically significant difference in the mean achievement scores of secondary school students instructed in biology using both ITS and traditional teaching methods with respect to gender.

METHODOLOGY

This investigation employed a quasi-experimental research design, specifically utilizing a non-randomized pretest-posttest control group framework. The study was conducted within the Esan West Local Government Area of Edo State, Nigeria. The target population comprised 1,833 Senior Secondary Class II (SSII) students from twelve public secondary schools in the locality during the 2025/2026 academic session. A sample of 88 SSII students (52 males and 36 females) was selected from two intact classes within a single coeducational public secondary school in Edo State. The school was chosen through a combination of purposive sampling and simple random sampling via balloting from the twelve coeducational public secondary schools.

The Biology Achievement Test (BAT), a standardized assessment instrument, was utilized for data collection. This test, adapted from previous West African Examinations Council (WAEC) questions, covered selected curricular topics including Genetics, Evolution, the Krebs Cycle, and Respiration. The BAT was designed to quantitatively evaluate students' academic achievement in biology and consisted of fifty multiple-choice items, each with four options labeled A to E. Each correct response was scored two marks, resulting in a total possible score of 100%. The BAT was administered as a pretest before the intervention and then reshuffled and re-administered as a posttest after a four-week treatment period.

To determine the reliability of the BAT, a pilot administration was conducted with 25 biology students outside the study area. Reliability analysis using the Kuder-Richardson Formula 21 (KR-21) yielded a coefficient of 0.82, indicating good reliability. This was because test items are scored dichotomously (0 or 1), all items measured the same construct, items have approximately equal difficulty levels, and the test was administered once. Data analysis involved computing means and standard deviations to address the research questions, while inferential statistics were conducted using Analysis of Covariance (ANCOVA) to test the hypotheses at a 0.05 significance level. Regarding hypothesis testing, the null hypothesis was rejected if the p-value was less than 0.05, and accepted if the p-value exceeded 0.05.

RESULTS AND DISCUSSION

Results

Research Question 1: What is the average achievement score of secondary school students instructed in biology through Intelligent Tutoring Systems (ITS)?

Table 1 displays the descriptive statistics, specifically the mean and standard deviation, of students' scores on both pre-test and post-test measures for the experimental group, which utilized an intelligent tutoring system, and the control group, which employed traditional instructional methods. Prior to the intervention, the experimental group had a pre-test mean score of 13.61 (SD = 4.71), while the control group had a comparable mean score of 13.42 (SD = 4.52), indicating equivalent baseline academic performance across groups. Following the instructional period, the experimental group achieved a post-test mean score of 75.73 (SD = 8.79), surpassing the control group's mean score of 69.12 (SD = 6.67). Additionally, the experimental group demonstrated a larger mean gain score of 62.30 relative to the control group's gain of 53.58, resulting in a mean difference of 8.72 favoring the experimental condition. These findings suggest that the implementation of the intelligent tutoring system contributed to enhanced academic outcomes compared to conventional teaching methodologies.

Table 1. Mean pre-test and post-test scores of Senior Secondary II students instructed through intelligent tutoring systems compared to those taught via traditional pedagogical approaches.

Treatment group	N	Mean Pre-test	SD	Mean Post-test	SD	Mean gain	Mean difference
Intelligent tutoring system (Experimental)	44	13.61	4.71	75.73	8.79	62.3	8.72
Conventional (control)	44	13.42	4.52	69.12	6.67	53.58	

Table 2. Mean Pre-test and Post-test Scores of Male and Female Students Instructed in Biology Using an Intelligent Tutoring System.

Treatment Group	Gender	N	Mean Pre-test	SD	Mean Post-test	SD	Mean gain	Mean Difference
Intelligent tutoring system	Male	36	11.52	2.51	46.42	5.31	34.90	0.91
	Female	52	12.14	3.40	46.13	5.03	33.99	

Table 2 delineates the descriptive statistics, specifically the mean and standard deviation, for male and female students who were taught Biology utilizing an intelligent tutoring system. The data indicate that male students exhibited a pre-test mean of 11.52 (SD = 2.51), whereas female students demonstrated a marginally higher pre-test mean of 12.14 (SD = 3.40). This suggests that prior to the intervention, both genders possessed comparable academic proficiency levels, albeit with females showing a slight advantage. Subsequent to engagement with the intelligent tutoring system, male students achieved a post-test mean score of 46.42 (SD = 5.31), while female students attained a post-test mean of 46.13 (SD = 5.03). The mean gains were 34.90 for males and 33.99 for females, resulting in a minimal mean difference of 0.91 favoring males. This negligible discrepancy implies that both male and female cohorts experienced nearly equivalent academic enhancement from the intelligent tutoring system. Consequently, the findings underscore that the intelligent tutoring system effectively augmented the academic performance of students irrespective of gender, with minimal differential impact.

Hypothesis I: posits that there is no statistically significant difference in the average academic performance of students instructed in Biology through an intelligent tutoring system compared to those taught via traditional lecture methods.

Table 3. Independent samples t-test of Biology achievement between students taught using the Intelligent Tutoring System (ITS) and those taught using the conventional teaching method.

Treatment group	N	Mean	SD	Df	T-cal	P-value
Intelligent tutoring system (Experimental)	44	75.73	8.79	86	3.97	<.05
Lecture method (control)	44	69.12	6.67			

Table 4. Analysis of Covariance (ANCOVA) determining the effects of instructional strategy and gender on students' achievement in Biology while controlling for pre-test scores.

Source	Type III sum of squares	Df	Mean square	F	P-value	Decisions
Corrected model	4767.237	3	1589.079	24952	.000	Significant
Intercept	34865.675	1	34865.675	453.423	.000	Significant
Pre-test	4.867	1	4.867	0.075	.775	Not significant
Instructional strategy	4867.131	1	4867.131	65.625	.000	Significant
Gender	8.441	1	8.441	0.140	.771	Not significant
Error	12645.706	97	130.368			
Corrected total	16583.844	101				

The independent samples t-test revealed a statistically significant difference in Biology achievement between students taught using the Intelligent Tutoring System (ITS) and those taught using the conventional teaching method, $t(86) = 3.97$, $p < .05$. Students exposed to the Intelligent Tutoring System obtained a higher mean post-test score ($\bar{X} = 75.73$, $SD = 8.79$) than those taught through the conventional method ($\bar{X} = 69.12$, $SD = 6.67$). Therefore, the null hypothesis of no significant difference was rejected. This finding indicates that the Intelligent Tutoring System was more effective in enhancing students' achievement in Biology than the conventional teaching method.

Hypothesis II: There is no statistically significant difference in the mean achievement scores of secondary school students instructed in biology using both ITS and traditional teaching methods with respect to gender.

Table 4 presents the results of the Analysis of Covariance (ANCOVA) conducted to determine the effects of instructional strategy and gender on students' achievement in Biology while controlling for pre-test scores. The corrected model was statistically significant, $F(3, 97) = 24.952$, $p < .05$, indicating that the independent variables collectively explained a significant proportion of the variance in students' post-test achievement scores. The covariate, pre-test score, yielded an F-value of 0.075 with a corresponding p-value of .775, which is greater than the 0.05 level of significance. This indicates that students' initial achievement levels did not significantly influence their post-test performance after the treatment. Therefore, differences observed in achievement cannot be attributed to prior knowledge or baseline academic ability. Instructional strategy recorded an F-value of 65.625 and a p-value of .000, which is less than .05. This result indicates a statistically significant effect of instructional strategy on students' achievement in Biology. Consequently, the null hypothesis stating that there is no significant difference in achievement between students taught using the Intelligent Tutoring System (ITS) and those taught using the conventional teaching method was rejected. Students exposed to the Intelligent Tutoring System performed significantly better than those taught through conventional instruction.

Gender produced an F-value of 0.140 with a p-value of .711, which exceeds the 0.05 significance level. This finding indicates that there was no statistically significant difference in Biology achievement between male and female students. Therefore, the null hypothesis stating that there is no significant gender difference in achievement among students taught using the Intelligent Tutoring System was accepted.

Overall, the findings demonstrate that instructional strategy was the major determinant of students' academic achievement, whereas gender and pre-test scores did not significantly influence performance. This suggests that the effectiveness of the Intelligent Tutoring System transcends gender differences and can enhance Biology achievement among both male and female students equally. The result further implies that integrating intelligent tutoring technologies into Biology instruction may provide substantial academic benefits

irrespective of students' gender or prior achievement levels.

DISCUSSION

In addressing the first research question, the results indicate that students who received instruction via the intelligent tutoring system (ITS) demonstrated superior academic performance relative to their counterparts taught through traditional pedagogical methods. Consequently, the ITS appears to exert a beneficial influence on students' academic achievement. Furthermore, hypothesis testing revealed that instructional strategies significantly impact academic outcomes, with the ITS-based approach yielding a statistically meaningful enhancement in student achievement compared to conventional teaching. This finding attributes the observed effect to the efficacy of the ITS. The underlying rationale is that ITS offers a more interactive, personalized, and learner-centered instructional paradigm than traditional methods. The experimental group's elevated post-test means scores and mean gains suggest that learners capitalized on immediate feedback, tailored learning trajectories, and a more engaging educational environment facilitated by the ITS.

This result aligns with the findings of Eryılmaz and Adabashi (2020), who reported that students utilizing Intelligent Tutoring Systems (ITS) exhibited significantly higher academic achievement on average compared to peers employing alternative instructional methods. Furthermore, these findings corroborate those of Hassan et al. (2023), who investigated the impact of a web-based innovative coaching system on students' performance and motivation in technical drawing within Niger, Nigeria. Their study concluded that web-based intelligent tutoring systems are more effective in enhancing student achievement and fostering engagement in technical drawing than conventional pedagogical approaches.

Similarly, Rababah (2023) conducted a quasi-experimental study examining the effects of an Intelligent Tutoring System (ITS) on the academic advancement and achievement of Jordanian EFL learners. The participants who received instruction through the ITS demonstrated marked improvements in their learning outcomes and academic performance. Specifically, the experimental group's post-test scores in grammar, vocabulary, and reading comprehension were significantly higher compared to those of the control group.

This result also aligns with the findings of Villegas. et al. (2025) who carried out a study on adaptive intelligent tutoring systems for STEM education: analysis of the learning impact and effectiveness of personalized feedback. The results show significant improvements in several key metrics. The experimental group achieved an average precision of 85% in programming and 78% in mathematics, significantly outperforming the control group. Also, a linear regression model identified a positive correlation between the time of interaction with the system and the rate of progress in fundamental concepts. These findings identify the system's potential to transform STEM teaching, address the lack of personalization, and improve learning in various educational settings.

Likewise, the study is also in harmony with the study carried out by Shih, et al. (2023) on mathematics intelligent tutoring system for learning multiplication and division of fractions based on diagnostic teaching. The results showed that the experimental group using the math ITS significantly outperformed the control group. Further analysis indicated that the math ITS had a significant effect on the lesser-performing group (the lower 75% in the pretest score). In addition, a usability and user experience survey showed that students were willing and likely to learn mathematics using the dialogue-based math ITS.

This study also corroborates with the study carried out by Liu, Zhang and Jia (2024) on the design of guiding and adaptive prompts for Intelligent tutoring systems and Its effect on students' mathematics learning. The findings analysis indicated that although the experimental group scored lower than the control group in the pretest, they scored higher in the posttest and spent less completion time. The drilled problems and the prompts provided to the experimental group students were personalized. In conclusion, the design principles for guiding and adaptive prompts in the ITS can provide personalized guidance and support for students, thus effectively improve their performance. Those principles are not only valuable for the subject mathematics but also can contribute significantly to the prompt design of other subjects, thereby bolstering the global pursuit of personalized education.

Research question 2 demonstrated that male and female students exhibited comparable academic performance, suggesting that both genders derived nearly equivalent benefits from the implementation of the intelligent tutoring system (ITS). Consequently, these findings imply that the ITS enhanced academic achievement across genders without a significant gender-based disparity. This indicates that the ITS was equally efficacious in fostering academic success for both male and female students. Statistical hypothesis testing corroborated this by showing no significant difference in student achievement attributable to gender, thereby leading to the acceptance of the null hypothesis. This conclusion contrasts with the findings of Schaaf et al. (2026), who investigated the influence of ITS usage frequency on mathematics learning gains among secondary school students in grades 7 and 8. Through multilevel analysis, they determined that the frequency of ITS use did not exert a significant effect on learning outcomes at either the individual or classroom level. Their results suggest that mere use of ITS does not inherently result in improved learning gains.

Hence, it can be reasonably inferred that instructional strategies exerted a significant and substantive influence on students' academic performance, even after accounting for pre-test scores. This suggests that the pedagogical approach serves as the principal factor affecting achievement in this research.

CONCLUSION

This study's results indicate that the implementation of an Intelligent Tutoring System (ITS) substantially enhances secondary school students' academic performance in Biology compared to traditional instructional methods. Learners utilizing the ITS achieved significantly higher post-test results and greater mean score improvements than their counterparts receiving conventional classroom instruction. These findings suggest that ITS offers a more effective, interactive, and learner-centered educational environment, which facilitates improved comprehension and retention of biological concepts. Additionally, the study found no significant gender disparities in academic outcomes with ITS usage, demonstrating that both male and female students derived comparable benefits from this technology-enhanced learning approach. The Intelligent Tutoring System represents a potent pedagogical methodology that has the potential to enhance students' academic performance in secondary school Biology.

RECOMMENDATIONS

Based on the findings of this study and within the limitations of its scope, the following recommendations are made:

1. Biology teachers in the study school and similar secondary school settings may consider incorporating Intelligent Tutoring Systems (ITS) into Biology instruction, as the findings suggest that ITS can enhance students' academic achievement in Biology.

2. School administrators should encourage the use of technology-supported instructional approaches and provide the basic technological facilities required for the effective implementation of Intelligent Tutoring Systems in Biology classrooms.

3. Teachers should provide equal opportunities for both male and female students to engage with Intelligent Tutoring Systems, since the study found no significant gender difference in students' achievement when taught using ITS.

4. Further studies should be conducted using larger samples drawn from multiple schools across different local government areas and states to determine the extent to which the findings can be generalized to a wider population of secondary school students.

Future researchers should investigate the effectiveness of Intelligent Tutoring Systems in other science subjects such as Chemistry and Physics, as well as at different educational levels, to provide broader evidence on the educational value of ITS in science education

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