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Intelligent Tutoring Instructional Strategy and Its Effects on Academic Achievement in Biology among Secondary School Students in Niger State, Nigeria

***Awoyeye, A.O., & Aghayere, O.F.**
Institute of Education, Yakubu Gowon University, Abuja, Nigeria

***Corresponding author email:** awoyeyeagnes@gmail.com

Abstract
The purpose of the study was to examine the effect of the Intelligent Tutoring Instructional Strategy on the academic achievement of secondary school students in Biology in Suleja Local Government Area of Niger State, Nigeria. A quasi-experimental pretest-posttest non-equivalent control group design was used for the study. The population of the study comprised 2,866 Senior Secondary School II students studying Biology. A sample of 120 students, comprising 68 males and 52 females, was selected for the study. The data collection instrument was a 25-item Biology Achievement Test (BAT), which was developed by the researchers. The test was validated by science education experts. A pilot test was carried out on 30 students outside the sample of the study. The reliability coefficient of the test was found to be 0.88 using the Kuder-Richardson 20 reliability test. The results of the study showed that students taught with the Intelligent Tutoring Instructional Strategy recorded higher academic achievement compared to students taught with the conventional lecture method. The results showed that the mean academic achievement of students taught with the Intelligent Tutoring Instructional Strategy was 8.80 compared to 3.45 recorded by students taught with the conventional method. The results of the study also showed that there was no significant gender difference among students taught with the Intelligent Tutoring Instructional Strategy.

Keywords: Biology, Academic Achievement, Intelligent Tutoring System, Instructional Strategy, Gender.

Introduction

Globalization has dramatically altered all facets of human activity and has put unprecedented pressure on countries and education systems around the world to produce scientifically literate graduates capable of thriving in the increasingly technology-dominated world that we live in today. Biology plays a central and strategic role among the main science subjects taught at the Senior Secondary School level in Nigeria and at the same time functions as the gateway for access to higher education in the health and biological sciences and as the means for the development of the environmental awareness and critical and practical scientific thinking of the students (Adeyemi & Olayemi, 2022). The Federal Government of Nigeria through its National Policy on Education recognizes the role of Biology in the development of the awareness of the environment of the students and equipping them with the knowledge required for living in a scientific and technological world and for the advancement of technology. However, despite the recognition of the importance of Biology as part of the education of the Nigerian child, many secondary school students continue to demonstrate low academic achievement in biological concepts. Reports from classroom observations and internal assessments in Nigerian secondary schools suggest that students often perceive biological concepts as abstract and theoretical. This has resulted in the pedagogical crisis that has been brought about by the widespread and prevalent use of conventional and traditional approaches to teaching and learning that fail to engage the learners cognitively and accommodate the various learning styles and ability levels that exist in heterogeneous secondary school settings.

The conventional teaching methods, which still dominate most science learning in Nigeria, are marked by unidirectional information transmission, low student interactivity, lack of content differentiation, and overreliance on linguistic information and blackboard illustrations (Dajal, 2023). All studies have consistently demonstrated that conventional teaching methods are not appropriate for the requirements of modern Biology learning, in which

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conceptual, process, and analytical applications are valued far more than the recall of verifiable data (Nwankwo, 2024; Okonkwo, 2022). The measurable effects include consistently low overall achievement grades in national exams, lack of adequate preparation of students for biology-related courses in higher institutions, and a widening gap between the learning outcomes that examiners require and the learning outcomes that conventional teaching methods can deliver. Gender issues add another dimension to the already complex and difficult situation. Although the literature reveals conflicting findings, a dominant theme in most studies in Nigerian science learning is that male students consistently outperform their female counterparts in Biology learning in conventional teaching settings, and this is attributed to gender-stereotyped societal expectations, unequal opportunities to learning resources, and teaching practices that reward competitive learning styles more than cooperative learning styles (Julius, Twoli & Maundu, 2018; Akinyemi & Sulaimon, 2025). Fully addressing these complex issues requires a resolute and data-driven move away from passive and one-size-fits-all teaching approaches and towards adaptive, personalized, and data-driven teaching approaches that have been shown to deliver superior learning achievement outcomes for the broad range of learning styles and characteristics.

One such pedagogical innovation with a growing and compelling evidence base is the Intelligent-Tutoring Instructional Strategy (ITS), an educational application of artificial intelligence and machine learning technologies that aims to replicate the tutoring role of an expert human tutor within a structured digital learning environment. Unlike static computer-assisted instruction packages, ITS functions through four highly integrated components: the domain model, the learner model, the tutor model, and the user interface, which work together to enable the system to diagnose the individual state of the learner in real-time, adapt instruction to the learner's cognitive level, and provide targeted and personalized feedback that scaffolds understanding progressively towards mastery (Sottilare, Graesser, Hu & Goldberg, 2014; Bhagat, Rodrigo & Chang, 2018). The growing international and local evidence base affirming the effectiveness of ITS in enhancing academic achievement across a range of subject areas, coupled with the obvious lack of empirical studies documenting its specific use within Nigerian secondary school Biology classrooms, provides a compelling and urgent rationale for the present study. This study was therefore conceptualized to investigate the impact of Intelligent-Tutoring Instructional Strategy on the academic achievement of senior secondary school Biology students in Niger State, Nigeria, with gender factored in as a moderating variable to determine the equity of instructional outcomes, in pursuit of the following specific objectives:

i. determine if any difference existed in the mean achievement scores of Biology students exposed to intelligent-tutoring Instructional Strategy (experimental group) and their counterparts in the control group;
ii. ascertain if gender difference existed in the mean achievement scores of Biology students taught with intelligent-tutoring Instructional Strategy.

Research Questions

The study was guided by the following research questions:

1. What is the difference in the mean achievement scores of Biology students exposed to Intelligent-Tutoring Instructional Strategy (experimental group) and their counterparts in the control group taught using the conventional method?

2. What is the difference in the mean achievement scores of male and female students taught Biology using Intelligent-Tutoring Instructional Strategy (experimental group)?

Research Hypotheses

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

H_{01}: There is no significant difference in the mean achievement scores of Biology students exposed to Intelligent-Tutoring Instructional Strategy and their counterparts in the control group.

H_{02}: There is no significant difference in the mean achievement scores of male and female students taught Biology using Intelligent-Tutoring Instructional Strategy.

Literature Review

Lately, science education researchers have argued on innovative pedagogical approaches to enhance student's achievement in Biology. Biology is an indispensable science subject in the secondary school curriculum due to the basic knowledge required for Medicine, Agriculture, Biotechnology and Environmental Science fields. In many developing countries of the world including Nigeria, achievement of students in Biology is still low which is as a result of continued dependence on the teacher-centered approach of instruction. In this approach, teaching

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is usually based on lectures which results to minimum involvement of students and consequently rote learning. Modern scholars therefore opine that improvement of students' achievement in Biology is necessitated by pedagogical approaches that make learners to be active and mentally involved in the concept they are learning (Adeyemi & Olayemi, 2022; Nwosu, 2022). Recent studies emphasize on instructional innovations and incorporation of technology in science education which should be in conformity with knowledge societies that demands for digital literacy and analytical thinking skills (Nwankwo, 2024).

The integration of intelligent and technology based instructional systems has received much attention in recent educational research literature with reference to the aforementioned issues. Intelligent tutoring systems (ITSs) can be identified as part of such systems due to their ability to use artificial intelligence techniques to mimic individual learning environment. Unlike conventional computer-assisted instructions, intelligent tutoring systems actively monitor the student's interaction with the system and provides feedback according to the learner's misconception or individual learning pace which can strengthen the student's comprehension and retention of complex science topics. Empirical studies show that intelligent tutoring systems improve students' academic achievement and motivation in science subjects, as found by Liu and Wang (2021) where AI-based tutoring systems have enabled learners to improve their concept of understanding by providing them with learning routes. Intelligent tutoring environments have enhanced students' motivation, participation and academic achievement in science classroom, based on the studies by Bakar and Zainuddin (2023). Studies related to computer assisted instruction have also demonstrated improved student's achievement in Nigeria (Okafor & Yusuf, 2022; Chinedu & Bello, 2023) hence technology based instruction strategies appear to be an ideal solution to students' persistent learning difficulty in biology.

One other factor highlighted in modern literature deals with gender differences in science achievement and the effects of new instructional strategies on these differences. Some past research had shown males performed better than females in science subjects owing to factors such as socio-cultural values and perceptions, classroom interactions and the distribution of resources and opportunities for learning. However, recent studies indicate that technology enhanced learning environments are likely to reduce these differences by ensuring equal opportunities for learning and individualized feedback. When a student interacts with an intelligent learning system, they are interacting with information on their individual learning pace, rather than as members of a competitive classroom and teacher-directed lesson. Akinyemi and Sulaimon (2025) for example found that the intelligent strategy had a minimizing effect on gender disparity in the achievement of biology subjects among secondary school students. Similarly, Mustapha, Umar and Idris (2023) asserted that digital learning provides both male and female students with equal opportunity for interaction and consequently equitable achievement. These indicate that it is plausible that the intelligent tutoring instructional strategies can be used not just to enhance Biology achievements but also to create equitable and balanced learning environment among secondary school students in science classroom.

Materials and Methods

The study adopted a quasi-experimental pretest-posttest non-equivalent control group design. It was designed to investigate the effect of the Intelligent Tutoring Instructional Strategy on the achievement of secondary school students in Biology. The experimental group was taught using Intelligent Tutoring System instructional strategy while the control group was taught using the conventional lecture method. The target population for the study comprised 2,866 SS II students offering Biology in all the secondary schools in Suleja Local Government Area of Niger State. The sample size for the study was 120 SS II students consisting of 68 males and 52 females. The instrument used to collect the data for the study was the Biology Achievement Test (BAT). It was a 25 item multiple-choice question test developed by the researcher to assess the academic achievement of the students in biology. The items were extracted from the topics studied in the lessons, including cell biology, transport systems of living organisms, digestion, excretion, ecology and some related fields.

The BAT were content validated by three experts in science education. This was to ensure that the questions were adequate and relevant in scope and coverage. Pilot test on 30 SS II students outside the samples was done and its reliability was calculated using the Kuder-Richardson formula 20 (KR-20) which was 0.88. This revealed the test to be highly reliable. The experiment lasted for five weeks. Before the treatment, the students in both the experimental and control groups were tested using the pre-test to assess their baseline level of achievement in Biology. Then, the experimental group was instructed using the Intelligent Tutoring System while the control group was instructed using the conventional lecture method. After the treatment period, the students in both the experimental and control group were tested using the post-test.

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The data obtained from the research instruments were analyzed using both descriptive and inferential statistics. The descriptive statistics included mean, standard deviation and mean gain score. The hypotheses of the study were tested using the independent samples t-test at 0.05 level of significance with the assistance of the Statistical Package for Social Sciences (SPSS).

Results

The results of the study were obtained from the research questions answered and the hypotheses tested for the study.

Research Question One

What is the difference in the mean achievement scores of Biology students exposed to Intelligent-Tutoring Instructional Strategy (experimental group) and their counterparts in the control group taught using the conventional method?

To answer research question one, the mean achievement score and standard deviation of students in both groups are presented in Table 1.

Table 1: ***Descriptive Statistics of Group's Pre-test, Post-test and Mean Gain Scores in Achievement***

Groups	No. of Students	Mean Scores		Standard Deviation	Mean Gain
		Pre-test	Post-test		
Intelligent Tutoring System (ITS)	60	9.80	18.60	0.52	8.80
Conventional	60	6.84	10.29	1.02	3.45
Mean Difference		2.96	8.31		**5.35**

Results in Table 1 show the mean achievement scores of students in Biology after exposure to Intelligent-Tutoring Instructional Strategy and the conventional lecture method. The results revealed that students in the experimental group had a pre-test mean achievement score of 9.80, a post-test mean achievement score of 18.60, and a mean achievement gain of 8.80. Their counterparts in the control group had a pre-test mean achievement score of 6.84, a post-test mean achievement score of 10.29, and a mean achievement gain of 3.45. The experimental group therefore recorded a higher mean achievement gain than the control group by a margin of 5.35 points, indicating that exposure to Intelligent-Tutoring Instructional Strategy was associated with substantially greater improvement in students' academic achievement in Biology compared to conventional instruction.

Research Question Two: What is the difference in the mean achievement scores of male and female students taught Biology using Intelligent-Tutoring Instructional Strategy (experimental group)?

To answer research question two, the mean achievement scores and standard deviations of male and female students in the experimental group were presented in Table 2.

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Table 2: ***Analysis of Male and Female Students' Pre-test, Post-test***

Gender	No. of Students	Mean Scores		Standard Deviation	Mean Gain
		Pre-test	Post-test		
Male	34	9.97	18.82	1.82	8.85
Female	26	9.80	18.62	1.54	8.82
Mean Difference		0.17	0.20		**0.03**

Results in table 2 shows that male students have a pre-test mean score of 9.97, a post-test mean score of 18.82 and mean gain of 8.85 while female students have a pre-test mean score of 9.80, a post-test mean score of 18.62 and mean gain of 8.82. Male students have a higher mean gain than the female students. This shows that male students taught some Biological concepts using the Intelligent Tutoring System achieved higher than their female counterparts.

Null Hypotheses

Hypothesis One

H_{01}: There is no significant difference in the mean achievement scores of Biology students exposed to Intelligent-Tutoring Instructional Strategy and their counterparts in the control group**.**

To test hypothesis one, an independent samples t-test comparing the mean achievement scores of ITS and conventional groups was presented in Table 3

Table 3: ***t-test Value on Achievement Scores of Students Exposed to Intelligent Tutoring System and the Control group***

Group	N	X	SD	df	t-value	Sig.(P)	Decision
Experimental	60	9.80	0.52				
				118	7.71	.000*	Reject
Control	60	6.84	1.02				

*Significant at P<.05

The results presented in Table 3 revealed that, at the 0.05 level of significance, a t-value of 7.71 was obtained at df = 118, with a Sig. value of 0.001. The Sig. value obtained is less than the 0.05 level of significance. Hence, the null hypothesis was rejected. This implies that there is a statistically significant difference in the mean achievement scores of Biology students exposed to Intelligent-Tutoring Instructional Strategy and those taught using the conventional lecture method, in favour of the experimental group.

Hypothesis Two

H_{02}: There is no significant difference in the mean achievement scores of male and female students taught Biology using Intelligent-Tutoring Instructional Strategy**.**

To test hypothesis two, an independent samples t-test comparing the mean achievement scores of male and female students in the experimental group is presented in Table 4.

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Table 4: t-test Value on Mean Achievement Scores of Male and Female Students Exposed to Intelligent Tutoring System

Gender	N	X	SD	df	t-value	Sig.(P)	Decision
Male	34	9.97	1.82				
				58	0.34	0.5112	Accept
Female	26	9.80	1.54				

- Not significant at P <.05

The result in table 4 shows that P-value of 0.5112 > 0.05 at 0.05 level of significance at degree of freedom of 58. Therefore the null hypothesis was accepted implying that there was no significant difference in the mean achievement scores of male and female students exposed to Intelligent Tutoring System-based instruction.

Discussion

The findings of this study have shown that students who were taught Biology using the Intelligent Tutoring Instructional Strategy (ITS) have achieved higher academic performance compared to those students who were taught using the conventional method. As can be seen in the study, the experimental group has achieved a higher mean score in the post-test and the mean gain compared to the control group. This has shown that the use of ITS has helped the students to improve their understanding of the concepts in Biology. Furthermore, the hypothesis testing has shown that there is a statistically significant difference between the two groups, and thus the null hypothesis has been rejected.The study showed that these results concur with previous reports that technology-based instructional strategies enhanced students' science academic achievement (Liu & Wang, 2021; Bakar & Zainuddin, 2023). Also, reports on computer-assisted instruction in Nigerian science class confirmed that students' science academic achievement increased with the utilization of the digital instructional strategies. (Okafor & Yusuf, 2022; Chinedu & Bello, 2023).

The superiority of the Intelligent Tutoring Instructional Strategy over the traditional lecture method could be explained by its user-centered nature and the individual learner differences among the students. Instead of the lecture method that makes a student to be a passive learner and gives room for very limited student-response, ITS is a learner-centered environment and that makes a student active and participant in the learning environment. Also, due to its ability to diagnose and diagnose learners' misconceptions and provide feedback that promotes the conceptual understanding and retention of the biological knowledge,ITS shows to be the best instructional strategy for this study. This study result agrees with the result that intelligent tutoring system enhanced students' understanding through personalized pathway and adaptive learning support (Liu & Wang, 2021). Also Nwankwo (2024) and Nwosu (2022) had earlier noted that instructional strategies that are active and that develop analytical thinking tend to bring about high academic achievement than the teacher-centered method.

The study also investigated the effects of gender difference on students' science academic achievement while being exposed to the Intelligent Tutoring Instructional Strategy. It was found that males and females performed almost equally well while being taught using ITS. Despite the slightly higher mean gain score for the male students than for females, the difference was not statistically significant and this lead to the acceptance of null hypothesis. This may mean that ITS provided a good, gender-equitable learning environment for male and female learners alike. This result confirms with that of Akinyemi and Sulaimon (2025) who stated that technological instructional strategies helped to reduce the gender disparity in science achievement because learners are allowed to learn at their own pace and individual capability. Mustapha, Umar and Idris (2023) also stated that digital learning environment provides inclusive participation among learners, male and female alike, and equal learning opportunities for them. Overall, the findings of the study demonstrate that the Intelligent Tutoring Instructional Strategy is an effective pedagogical approach for improving students' academic achievement in Biology while simultaneously promoting gender equity in learning outcomes. The strategy enhances student engagement, supports individualized instruction, and provides adaptive feedback that strengthens conceptual understanding. These outcomes reinforce the growing body of research advocating the integration of intelligent and technology-supported instructional systems into science education as a means of improving learning outcomes and addressing

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persistent challenges associated with low academic achievement in Biology (Bakar & Zainuddin, 2023; Nwankwo, 2024).

Conclusion

The findings from this research have provided strong empirical evidence that the Intelligent Tutoring Instructional Strategy has a great impact on students' achievement in Biology when compared with the lecture instructional method in secondary school level in Niger State, Nigeria. In particular, students under ITS-mediated instructional context gained higher levels of achievement, thereby showing that technology-supported adaptive teaching methods can be very effective for the acquisition of concepts and achievement in sciences. Similarly, it was observed that there was no significant gender difference among students taught using ITS, which means that the ITS provides gender fairness to all learners. This supports the recent global call that effective adoption of intelligent and individualized computer learning system in the classroom instruction has the capacity to solve the age-long problems of poor achievement in sciences. It thus means that the adoption of Intelligent Tutoring Instructional Strategy as a pedagogical approach to teach Biology in secondary school could be a useful step toward enhancing Biology achievement, creating equity, and strengthening science education.

Recommendations

1. Based on the research objectives and findings, the following recommendations are proposed:
   1. Biology teachers in secondary schools should adopt the Intelligent Tutoring Instructional Strategy as an instructional approach in teaching biological concepts.
2. Government and educational stakeholders, particularly the Niger State Ministry of Education and Federal Ministry of Education, should provide adequate technological infrastructure such as computers, reliable electricity supply, and appropriate educational software in secondary schools.
3. Teachers should be trained through workshops, seminars, and professional development programmes on how to effectively use Intelligent Tutoring Systems and other technology-based instructional strategies.
4. Teachers and school administrators should encourage both male and female students to actively participate in technology-supported learning environments such as ITS..
5. Curriculum developers and educational authorities should incorporate technology-supported instructional strategies, including Intelligent Tutoring Systems, into the secondary school Biology curriculum.
6.

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