ISSN: 3355 - 3474
Volume 12, Number 1, 2026
Journal of International Science Education and Technology

PEDAGOGICAL INNOVATIONS IN SCIENCE EDUCATION: EXPLORING THE IMPACT OF TECHNOLOGY-ENHANCED LEARNING ON SECONDARY SCHOOL STUDENTS' PERFORMANCE AND RETENTION IN BIOLOGY IN TARABA STATE, NIGERIA

IGOH Sunday Adah and AUDU Christina Tanko, PhD
igohsunny@gmail.com, tankochristina@gmail.com
Department of Science Education, Taraba State University, Jalingo, Nigeria

Abstract
The integration of technology-enhanced learning in science education has revolutionized the way students learn and interact with complex concepts. This study examines the effect of technology-enhanced learning on the performance and retention of secondary school students in biology in Taraba State, Nigeria. The study utilizes Computer-Assisted Instruction (CAI) to enhance the effectiveness of the learning process. Computer-Assisted Instruction (CAI) has revolutionized the way science subjects are taught, offering numerous benefits that enhance students' learning experiences. A PowerPoint presentation was utilized as part of the Computer-Assisted Instruction (CAI). The study employed a quasi-experimental design with pre-test, post-test, and post-post-test phases. The study's population consisted of 1,290 SSII biology students. The schools were chosen using a multistage sampling technique. Two SSII-class coeducational government-owned schools were specifically chosen. Random sampling was then used to select one intact classroom from each of the sampled schools, for a total of two complete classes. 75 students from one of the two intact classrooms were assigned to the experimental group, while 55 students were assigned to the control group. A total of 130 SSII students were selected from the two classes that remained intact. Two research questions, two objectives, and two hypotheses were put out to direct the investigation. The Biology Performance Test was used as the data gathering tool (BPT). 0.81 was the reliability coefficient for BPT. ANCOVA was used to test the hypotheses at the 0.05 level of significance, and the mean and standard deviation were utilized to answer the study questions. Results obtained indicated that a significant difference exists in the mean performance scores of students taught skeletal systems using CAI (30.27) and those taught using GDI (24.68), as well as the mean retention scores of students in CAI (28.62) and GDI (21.55). It was concluded that Computer-Assisted Instruction is more effective than the Guided Discovery Strategy in promoting students' performance and retention in biology. It was recommended that teachers of biology should adopt Computer-Assisted Instruction as a teaching Strategy to promote students' performance and retention, and Government and School authorities should provide adequate, well-equipped Computer laboratories for the effective teaching and learning of Biology to boost students' performance and retention.

Keywords: Pedagogical Innovations, Technology-enhanced learning, Guided Discovery Strategy, Performance, Retention

Introduction
The integration of pedagogical innovations in science education has revolutionized the way students learn and interact with complex concepts. Technology-enhanced learning (TEL) has emerged as a vital tool in enhancing students' performance and retention in science-related fields such as biology. In Nigeria, the adoption of TEL has shown promising results in improving academic outcomes. Studies have demonstrated that innovative pedagogies, such as the learning activity package (LAP) and problem-based learning (PBL), significantly enhanced students' knowledge retention and academic performance in science subjects (Udu etal., 2022; Usman etal., 2023). These approaches foster active learning, critical thinking, and problem-solving skills, ultimately leading to improved academic performance.

The use of technology in science education has also been linked to improved student engagement and motivation. Digital tools, such as multimedia projectors and interactive

whiteboards, can make complex biological concepts more accessible and engaging for students (Akinwumi, 2024). Moreover, technology-enhanced learning environments can provide students with opportunities for self-directed learning and personalized feedback. Research has also shown that technology-enhanced learning can help bridge the gap in access to quality education, particularly in underserved communities. In Nigeria, where educational resources are often limited, TEL can provide students with access to high-quality educational content and resources (Omeodu, 2024). However, the effective integration of technology in science education requires careful planning and implementation. Teachers need training and support to effectively utilize digital tools and resources in their teaching practices (Adelakun, 2022). Technology breakthroughs, shifting pedagogical theories, and a deeper understanding of the diverse learning demands are all contributing to the current profound transformation in the field of education. Innovative and successful teaching techniques are increasingly in demand in science education, particularly in the teaching of biology (Subramaniam, 2015). This implies that the field of education is rapidly undergoing a significant transformation as a result of technological advancements. The influence of science and technology on contemporary life is unquestionable. Every facet of our existence, ranging from the gadgets we utilize to the meals we consume, is shaped by progress in science and technology (Ahmed, 2023). The increasing use of technology in education has transformed the way students learn, making it more accessible and engaging (Wekesa & Amadalo, 2013).

In teaching science-based subjects, technology-enhanced learning and approaches such as the integration of Information and Communication Technology (ICT) make the learning environment and process more flexible, enjoyable, motivating, and attractive by increasing students' attention to the subject content and promoting the effective teaching and learning processes, especially when visuals and animations are incorporated (Tomljenović & Zovko, 2016). One of the ICT packages is the use of Computer-Assisted Instruction (CAI), which has become an essential tool in the teaching and learning process, enabling students to acquire knowledge more effectively (Keziah, 2016) in science subjects such as Biology. In Nigeria, Biology occupies a central position among all science subjects. It is a core subject for Agricultural science, Nursing, Medical science, Pharmacy, Synthetic industry, Textile science, and Chemical technology. Research evidence has proved that Biology contributes to the quality of life and nation-building in all aspects of human endeavour (Abimbola, 2015). Therefore, for any meaningful development to take place, every nation must embark on the knowledge and skills of science and technology (including Biological Sciences) for rapid and sustainable social, economic, political, and technological advancement. The subject, as a fundamental science subject, has significantly contributed to our understanding of the world and our body system (UNESCO, 2020). Its applications in genetics, genetic engineering, and biotechnology have improved healthcare, food security, and environmental conservation (FRN, 2020). The Nigerian secondary school curriculum recognizes the importance of Biology in scientific and economic development, emphasizing the need for students to acquire relevant knowledge and skills (National Policy on Education, 2019).

Gimba etal., (2014) in a study revealed that students' performance was significantly improved when they were exposed to the Computer-Assisted Instruction (CAI) strategy. Furthermore, the use of Information and Communication Technology (ICT) in teaching Biology enhances students' understanding of complex concepts through interactive and engaging multimedia resources (Wekesa & Amadalo, 2013). This explains without any iota of ambiguity why the National Policy on Education advocates for the use of discovery approaches such as demonstration, practical work, and project-based learning to promote effective teaching and learning (FRN, 2020). To achieve these objectives, educators must adopt innovative teaching strategies and resources, including audio-visual and media materials, to sustain students' attention and interest (Onasanya et al., 2017). The integration of technology in education is crucial for national development, as it enhances educational advancement and technological progress (Egbodo, 2016).

At the secondary school level in Nigeria, students' failure in Biology is due to a lack of laboratory, unprofessional and inexperienced biology personnel, high population in the classes,

which affects class control, poor mode of instructional delivery, among others (Akanbi and Kolawole, 2014). Some researchers have attributed the students' poor performance in Biology to the abstract concepts of internally situated organs and systems, such as the skeletal system, which is the main focus of the study, as most schools ordinarily could not easily access the model of a skeleton (Singer, 2015).

The skeletal system is a complex system that consists of bones, cartilage, ligaments, tendons, and other connective tissues that provide support, protection, and movement to the human body. It is also known as the musculoskeletal system that provides support, protection, and movement to the human body (Guyton & Hall, 2016). It consists of 206 bones, cartilage, ligaments, tendons, and other connective tissues that work together to provide support, protect internal organs, facilitate movement, and produce blood cells, among others (Marieb & Hoehn, 2019). The understanding of this internal biological concept by students depends largely on the use of an appropriate teaching strategy.

The teachers' teaching strategies play a significant role in improving the teaching and learning process. A student-centered approach supported by the integration of more advanced technology-based and modern strategies, such as Computer-Assisted Instruction (CAI), could enhance effective teaching and learning. This is why this study explored the effect of advanced modern instructional strategies on secondary school students' performance and retention through the use of instructional strategies such as the Computer-Assisted Instruction (CAI) and Guided Discovery strategy in Taraba State.

In Taraba State, there has been a growing concern about the poor performance of students in science subjects, including Biology (Nwazor, 2015). The introduction of Computer-assisted Instruction aims to address this issue, but its impact on students' performance needs to be thoroughly examined. Performance in education refers to the ability of students to achieve academic goals as measured by standardized tests, assessments, and other evaluative tools. Academic performance is a critical indicator of the effectiveness of educational systems and teaching methodologies, and it has been linked to various factors, including socio-economic background, instructional strategies, and student motivation (Adeyemi, 2018). Globally, the emphasis on academic performance has intensified due to its impact on individual career prospects and national development. Understanding the multifaceted nature of performance in education is essential for devising strategies that can enhance learning outcomes across different contexts (UNESCO, 2022). According to a study by Ekundayo (2022), student retention is still a major issue in education since it has a big influence on students' ability to effectively finish their courses. Research has consistently shown that student retention is influenced by various factors, including academic preparedness, social integration, and institutional commitment.

Statement of the Problem

Despite biology's importance in comprehending the life sciences and its applicability in various sectors, students' performance and retention in the subject remain issues in Nigerian secondary schools, particularly in Taraba State. This is because traditional teaching methods frequently fail to effectively engage students, resulting in poor academic performance and low retention of biological concepts. Limited access to modern learning materials and laboratory equipment is one of the difficulties that biology students in Taraba State secondary schools face. As a result, they struggle to visualize and comprehend intricate biological processes and do not fully develop their critical thinking and problem-solving abilities. The usefulness of Computer-Assisted Instruction (CAI) as a component of a technology-based approach and the Guided Discovery Strategy in the specific setting of Taraba State secondary schools remains little understood, despite their demonstrated significant improvements in scientific education and other educational contexts. Given this context, the purpose of this study is to explore how Computer-Assisted Instruction (CAI) and Guided Discovery Strategies affect the performance and retention of Secondary School Biology Students in Jalingo Local Government Area, Taraba State, Nigeria.

Purpose of the Study

The main purpose of the study is to explore the impact of technology-enhanced learning on secondary school students' performance and retention in biology in Jalingo Local Government Area, Taraba State, Nigeria. Specifically, the study aimed to:

1. Investigate the effects of Computer-Assisted Instruction (CAI) and Guided Discovery on Secondary School Students' Performance in Biology in Jalingo Local Government Area, Taraba State, Nigeria
2. Determine the effect of Computer-Assisted Instruction (CAI) and Guided Discovery on Secondary School Students' Performance in Biology in Jalingo Local Government Area, Taraba State, Nigeria

Research Questions

The following research questions were raised to guide the study:

1. What are the Mean Performance scores of students taught Biology using Computer-Assisted Instruction (CAI) and those taught using Guided Discovery strategies?
2. What are the Mean Retention scores of students taught Biology using Computer-Assisted Instruction (CAI) and those taught with Guided Discovery strategies?

Hypotheses

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

HO_1: There is no significant difference in the mean performance scores of students taught Biology using Computer-Assisted Instruction (CAI) and those taught with the Guided Discovery Strategy

HO_2: There is no significant difference in the mean retention scores of students taught Biology Computer-Assisted Instruction (CAI) and those taught with the Guided Discovery Strategy.

Research Methods

For the pretest, posttest, and post-posttest, the study employed a quasi-experimental design with experimental and control groups. Before starting treatment for four weeks, the experimental and control groups underwent pre-testing to ensure group equivalence. Students' performance was evaluated with a post-test following the treatment, and retention was evaluated with a post-post-test two weeks later. The study was conducted in Taraba State's capital, Jalingo Local Government Area, Nigeria. With 2,381 male and 1,381 female students, 4,804 Secondary School (SSII) biology students in Jalingo Local Government Area, Taraba State (Post Primary Management Board, Taraba State Ministry of Education) comprised the study's target group. The sample size was 130 SSII students. The multi–stage random sampling technique was used in forming the sample for the study. Two public secondary schools with well-equipped computer laboratories, qualified teachers, and laboratory assistants were purposively selected from the local government to participate in this research, ensuring a conducive environment for reliable data collection and accurate results. One of the schools was designated as the experimental group (CAI) while the other one was designated as the control group (GDI). The purposive sampling technique was used in selecting the sample size.

The Biology Performance Test (BPT) was utilized to collect the data. Following pilot testing, BPT's reliability coefficient was obtained at 0.81. 50 multiple-choice questions drawn from previous West African Secondary School Certificate Examination (WASSCE) and Secondary School Certificate Examination (SSCE) examination questions made up the Biology Performance Test (BPT). Every item on the test consisted of a multiple-choice question with four alternative answers (A–D). The experimental and control groups were given this as a pretest, posttest, and post-posttest. In order to mitigate the impact of the pretest and posttest, the posttest's questions were rearranged and given in a different random order. Three experts from the Department of Science Education, Taraba State University, Jalingo, evaluated the instrument's content and offered suggestions that were included to improve its validity and accuracy.

The study was conducted in three phases: pre-test administration, four-week treatment phase, and post-test administration, with the researcher supervising the administration of instruments in both schools two weeks after the post-test. The data collected in this study were analyzed using descriptive statistics (Mean and Standard Deviation) to answer the research questions, and Analysis of Covariance (ANCOVA) was used to test the hypotheses at a 0.05 significance level. Two intact classes were used for four weeks, one taught using the Computer-Assisted Instructional strategy and the other using the Guided Discovery strategy.

RESULTS

Research Question One: What are the mean performance scores of students taught biology using computer-assisted instruction (CAI) and those exposed to the same concept using a Guided Discovery Strategy?

Table 1: Mean performance score of students exposed to Computer-Assisted and those exposed to Guided Discovery Strategy

Group	N	Pretest Mean	Std. Dev	Posttest Mean	Std. Dev	Mean Gain
Computer-power point	75	20.13	2.391	29.86	3.029	9.73
Guided Discovery strategy	55	18.72	2.301	25.17	4.211	7.07
Mean Differences		1.41		4.69		2.66

The mean scores and standard deviations of the performance scores of students taught Biology using Computer-Assisted Instruction (CAI) and Guided Discovery strategies are displayed in Table 1. The mean scores of students in the Computer-Assisted group were 19.13 in the pretest and 29.86 in the posttest, with standard deviations of 2.391 and 3.029 for the performance test; students in the Guided Discovery strategy group had mean scores of 18.72 and 25.17 in the pretest and posttest, respectively, with standard deviations of 2.301 and 4.21; additionally, the mean gain scores for the Computer-Assisted and Guided Discovery strategies were 9.73 and 7.07, respectively. These findings suggest that students benefited more from the use of Computer-Assisted learning than those exposed to the Guided Discovery strategy.

Research Question Two: What are the mean retention scores of students taught biology using computer-Assisted and those exposed to Guided Discovery strategy?

Table 2: Mean retention score of students exposed to the Computer-Assisted and those exposed to the Guided discovery strategy

Group	N	Posttest Mean	Std. Dev	Retention Mean	Std. Dev	Mean Gain
Computer-power point	75	30.27	3.029	28.62	2.870	1.65
Guided Discovery strategy	55	24.68	4.211	21.55	3.143	3.13
Mean Differences		5.59		7.07		1.48

The mean retention scores and standard deviations of biology students taught with computer-assisted instruction vs those taught with guided discovery are displayed in Table 2. Students in the computer-assisted group had mean retention scores of 30.27 on the posttest and 28.62 on the post-posttest, with retention test standard deviations of 3.029 and 2.87, respectively. Posttest and post-posttest mean retention scores for students in the Guided Discovery strategy group are 24.68 and 21.55, respectively, with standard deviations of 4.21 and 3.143. Additionally, the mean retention difference between the Guided Discovery approach and the Computer-Assisted approach group was

found to be 1.48. This implies that, compared to their peers using the Guided Discovery approach, the students in the Computer-Assisted group retained more of what they were taught.

Hypothesis One: There is no significant difference in the mean performance scores of students taught biology using computer-Assisted and those exposed to Guided discovery strategy.

Table 3: ANCOVA for the Mean performance score of students taught Biology using Computer-Assisted and those exposed to Guided Discovery Strategies

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1573.121[a]	2	786.560	63.251	.000	.417
Intercept	1160.120	1	1160.120	93.291	.000	.345
Pretest	168.189	1	168.189	13.525	.000	.071
Treatment	**1116.393**	**1**	**1116.393**	**89.775**	**.000**	**.337**
Error	2201.079	177	12.435			
Total	140560.000	130				
Corrected Total	3774.200	129				

a. R Squared = .417 (Adjusted R Squared = .410)

Table 3 presents a one-way ANCOVA analysis of covariance to compare the effect of the Computer-Assisted and Guided Discovery method on students' performance in Biology. The result F (1, 177) = 89.775, P = .000 < 0.05 shows that the two groups differ significantly. Thus, the null hypothesis is rejected. Therefore, there is a significant difference in the mean performance scores of students taught Biology with computer-assisted instruction compared to those taught using the Guided Discovery strategy. The effect size (eta square =.337) indicates that 33.7% of the difference in the mean score is based on the treatment used.

Hypothesis Two: There is no significant difference in the mean retention scores of students taught biology using computer-assisted and those exposed to the Guided discovery strategy.

Table 4: ANCOVA for Mean retention score of Students taught Biology using Computer-Assisted and those exposed to Guided Discovery Strategies

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2879.206[a]	2	1439.603	261.025	.000	.747
Intercept	367.061	1	367.061	66.555	.000	.273
Posttest	631.156	1	631.156	114.440	.000	.393
Treatment	**494.541**	**1**	**494.541**	**89.669**	**.000**	**.336**
Error	976.189	177	5.515			
Total	118213.000	130				
Corrected Total	3855.394	129				

3. R Squared = .747 (Adjusted R Squared = .744)

Table 4 is a one-way ANCOVA between groups' analysis of covariance to compare the effect of Computer-Assisted and Guided Discovery strategies on students' retention. The result F (1, 177) = 89.669, P = .000 < 0.05 shows that the two groups differ significantly. Thus, the null hypothesis is rejected. Therefore, there is a significant difference between the mean retention scores of students taught Biology with computer-Assisted and those taught using the Guided Discovery strategy. The effect size (eta square =.336) indicates that 33.6% of the difference in the mean score is based on the treatment used.

Discussion of findings

The present study investigated the effectiveness of Computer-Assisted and guided discovery strategies on students' performance and retention in biology. The results showed that students taught using a computer-assisted strategy performed significantly better than those taught using the Guided discovery strategy. This finding agrees with other studies that have reported the effectiveness of technology-based instructional methods in promoting students' learning outcomes. Gimba etal., (2014) in a study revealed that students' performance in Biology was significantly improved when they were exposed to the Computer-Assisted Instruction (CAI) strategy. More so, Egbodo (2016) found that students who received instruction using multimedia presentations outperformed those who received instruction through traditional instruction. Similarly, a study by Adeyemi (2020) reported that students who used interactive multimedia modules showed significant improvement in their understanding of biological concepts compared to those who used traditional textbooks. This implies that the Guided discovery strategy may be more effective in promoting deep learning and understanding of scientific concepts, whereas the present study found that the computer-assisted strategy was more effective in promoting students' performance and retention than the Guided discovery strategy.

Conclusion

Consequently, the study concludes that the Computer-Assisted Strategy is more effective and has a greater impact on students' performance and retention in biology than the Guided Discovery Strategy.

Recommendations

Based on the study's findings, the following recommendations are made:

1. Biology teachers should adopt technology-enhanced strategies, such as the use of Computer-Assisted Instruction (CAI), to promote students' performance in the subject
2. The government and school authorities should make sure that sufficient and well-equipped computer laboratories are provided for the effective teaching of biology to boost students' performance and retention.

REFERENCES

Abimbola, I. O. (2015). The one hundred and twenty-third (123rd) inaugural lecture: The misunderstood word in science: towards a technology of perfect understanding for all. Ilorin: University of Ilorin.

Adelakun, N. O. (2022). Impact of digital technology and the need for periodical review of educational curriculum in Nigerian tertiary institutions.

Adeyemi, K. T. (2020). Effect of PowerPoint presentations and guided discovery on gender performance in the English language in Ekiti State, Nigeria

Ahmed, A. (2023). The impact of science and technology on modern life. *Journal of Science and Technology*, 12(1), 1-5.

Akinwumi, I. O. (2024). The role of technology on biology education in Nigerian secondary schools: A review.

Egbodo, A. (2016). The role of technology in education. Journal of Educational Technology, 10(2), 1-8.

Ekundayo, H. T. (2022). Student retention in higher education: A review of the literature. *Journal of Educational Research and Practice*, 12(1), 1-15.

FRN (20120). National Policy on Education. Federal Republic of Nigeria; Revised.

Keziah, A. (2016). The importance of computer technology in education. Journal of Educational Computing Research, 44(4), 419-428.

Gimba, R. W., Hassan, A. A., Abdulrahman, M. A., & Bashir, A. U. (2014). Effects of Computer-Assisted Instructional Package on achievement and Interest of Senior Secondary School students in Mathematics in Bida Metropolis, Niger State, Nigeria. Sokoto Educational Review

Guyton, A. C., & Hall, J. E. (2016). Textbook of Medical Physiology. Philadelphia, PA Saunders.

Marieb, E. N., & Hoehn, K. (2019). Human anatomy & physiology. Boston, MA: Pearson.
National Policy on Education (2019). Federal Republic of Nigeria

Nwazor, C. O. (2015). Poor performance in science subjects: A challenge to science education in Nigeria. Journal of Science Teachers Association of Nigeria, 45(1), 1-9.

Omeodu, M. D. (2024). Innovations for pedagogical learning in science education in the era of COVID-19: Focusing on information and communication technology

Onasanya, S., Shehu, R., Ogunlade, O., & Adefuye, T. (2017). The impact of technology on education. *Journal of Technology and Education*, 6(1), 1-10.

Renau, M. L. R. (2023). Exploring Methodological Approaches in Secondary Education in Castellón, Spain: A Comparative Analysis of Traditional, Blended, and Innovative Teaching. *Futurity Education*, *3*(4), 232-254.

Singer, T. (2015). Why biology students have misconceptions about science.

Subramaniam, K. (2015). "Student teachers' conceptions of teaching biology." *Journal of Biological Education* 48 (2): 91-97.

Tomljenović, K., & Zovko, V. (2016). The Use of ICT in Teaching Mathematics - A Comparative Analysis of the Success of 7th Grade Primary School Students. Croatian Journal of Education, 18(Special Issue edition 2, 215–221.

Udu, D. A., Nmadu, J., Uwaleke, C. C., Anudu, A. P., Okechineke, B. C., Attamah, P. C., Chukwuemeka, C. O., Nwalo, C. N., & Ogonna, O. C. (2022). Innovative pedagogy and improvement of students' knowledge retention in science education: Learning activity package instructional approach. *Pertanika Journal of Social Sciences & Humanities*, 30(3), 1405-1426.

Usman, G. B. T., Ali, M. N., & Ahmad, M. Z. (2023). Effectiveness of STEM problem-based learning on the achievement of biology among secondary school students in Nigeria. Journal of Turkish Science Education, 20(3), 453-467

UNESCO (2013). The importance of biology in modern life. United Nations Educational, Scientific, and Cultural Organization.

UNESCO. (2022). Gender and Education.

Wekesa, J., & Amadalo, M. (2013). The use of ICT in teaching biology. *Journal of Science Education and Technology*, 22(1), 1-9.