IMPACT OF AI-BASED LEARNING SYSTEMS ON ACADEMIC PERFORMANCE IN BIOLOGY AMONG SENIOR SECONDARY SCHOOL STUDENTS IN KATSINA STATE

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Abstract

This study examined the impact of Artificial Intelligence (AI)-based learning systems on academic performance of senior secondary school students in Biology in Katsina state. One of the key objectives was to examine the impact of AI-based learning systems on the academic performance of senior secondary school students in Biology compared to the traditional **lecture method** .The study adopted a quasi-experimental design. From a total population of 8,206 students, a sample of 150 participants was selected using stratified random sampling. Data was collected using a self-constructed and experts validated instrument titled AI-Based Biology Instructional Assessment (AIBBIA), which yielded acceptable reliability (Cronbach's $\alpha = .78$). The research question was answered using mean and standard deviations, while t-test for independent samples was used to test the hypothesis at 0.05 level of significance. The findings revealed the AI-based learning systems enhances students' academic performance than the traditional lecture method. The study recommends integrating AI based learning tools into the Biology curriculum and training of teachers to ensure effective implementation.

Keywords: Impact, AI- Based Learning System, Academic performance.

Introduction

Artificial Intelligence (AI) refers to the capability of machines to simulate intelligent human behaviors such as reasoning, problem-solving, learning, and understanding natural language (Russell & Norvig, 2016). In education, AI is increasingly being integrated to improve learning outcomes by providing adaptive content, automating feedback, and offering real-time support to both learners and teachers (Luckin, 2017). This integration is especially promising in science subjects like biology, which often require visualization, abstraction, and conceptual understanding that traditional teaching methods struggle to deliver effectively.

AI-based learning system, conceptualized as a digital learning platform or tool that leverages artificial intelligence to personalize instruction, adapt to individual learner progress, and offer interactive features such as intelligent tutoring, simulations, and real-time assessment feedback. These systems are capable of identifying gaps in student understanding and modifying content delivery accordingly. In the context of biology education, AI tools can simulate biological processes, provide visual representations of complex systems, and engage students in exploratory learning. By doing so, AI-based systems serve as a technological enhancement to traditional instructional methods.

The **academic performance in biology**, operationalized as students' achievement levels based on assessments that measure their understanding of Biology concepts. Academic performance in this context includes students' ability to recall, apply, and analyze biological knowledge taught during instruction. Poor academic performance in biology is often attributed to a lack of student engagement, difficulty in grasping abstract concepts, and limited use of learner-centered instructional strategies. As a result, many students struggle with the subject, leading to high failure rates and diminished interest in science careers.

The study, therefore, investigates the impact of AI-based learning systems on the academic performance of senior secondary school students in Biology in Katsina Local Government Area (LGA) of Katsina State, Nigeria. It aims to determine whether the use of AI tools can enhance learning outcomes and contribute to the realization of functional education objectives that support national development and security. Therefore, this study seeks to **fill a critical gap in empirical research** by investigating the **impact of AI-based learning systems on the academic performance of senior secondary school students in biology** within Katsina Local Government Area of Katsina State, Nigeria.

By evaluating how AI interventions affect students' mastery of biological concepts, this research contributes to the growing body of literature advocating for technology-enhanced learning. It also provides practical insights for educators, policymakers, and technology developers on the viability and effectiveness of AI integration in Nigerian classrooms. The integration of Artificial Intelligence (AI) in education has attracted growing interest among educators and researchers due to its potential to transform traditional pedagogical methods and improve learning outcomes. In recent years, AI-based learning systems have been used to create adaptive and personalized learning environments that cater to students' individual needs, learning styles, and academic abilities (Luckin et al., 2017). These systems rely on machine learning algorithms to monitor learner progress, identify areas of weakness, and provide tailored feedback and content delivery (Kuldeep Singh & Kaswan et al., 2024).

Incorporating Artificial Intelligence (AI) into education offers new opportunities to enhance functional learning outcomes. AI technologies can support personalized learning, foster critical thinking, and increase access to quality instruction, particularly in underserved areas. These innovations not only improve academic performance but also prepare learners with digital competencies needed for participation in the knowledge economy (Feldstein, 2019; Olanrewaju & Okoye, 2022).

In the Nigerian educational policy landscape, efforts have been made to integrate technology and STEM education into national curricula. The National Policy on Education (NPE) emphasizes science and technology education as a means to foster innovation and sustainable development (Federal Republic of Nigeria, 2014). However, implementation gaps persist, particularly in rural and underserved regions where access to digital infrastructure remains limited.

AI applications in education range from intelligent tutoring systems and learning analytics to automated grading, personalized learning paths, and real-time feedback systems. For example, platforms like Carnegie Learning and Knewton have shown positive results in adaptive learning, with increased student motivation and improved learning efficiency (Knewton, 2016). According to Russell and Norvig (2016), AI's capability to simulate human intelligence makes it a powerful tool for automating complex educational tasks and providing real-time support to learners.

Science subjects, particularly biology, present unique challenges due to their abstract concepts and high cognitive demands. Many students find it difficult to grasp topics like cell division, genetic processes, and ecological systems through conventional lecture methods. AI-based learning systems address these challenges through interactive simulations, virtual labs, and 3D models that make science more tangible (Tamim et al., 2011). Ghasa Faraasyatul 'Alam et al. (2024) emphasized that immersive, AI-powered experiences deepen understanding and improve student retention of complex topics.

Despite global advancements, the implementation of AI-based learning tools in Nigerian secondary schools is still emerging. Most schools rely on traditional teaching methods with minimal technological integration. Studies by Nwoke et al. (2022) and Kelp et al. (2023) highlight a lack of infrastructure, teacher training, and access to digital resources as barriers to effective technology integration. However, some pilot projects have shown promise. For instance, Eden et al. (2024) demonstrated that even low-cost AI tools significantly improved students' science comprehension in rural settings. While several international studies have explored the benefits of AI in education, limited empirical research has been conducted within the Nigerian context, particularly regarding its impact on biology learning outcomes (Okebukola, 2020).

This study is anchored on two key learning theories: Constructivism posits that learners build knowledge through experiences and reflection. AI-based systems align with this theory by providing interactive, student-centered environments where learners actively construct biological concepts through simulations and feedback, and the Cognitive Load Theory (Sweller, 1988). This theory emphasizes the importance of managing cognitive load during instruction. AI systems can reduce extraneous cognitive load by customizing content delivery, helping student's process complex biological information more efficiently.

Statement of the problem

Despite sustained policy interventions and curriculum reforms aimed at strengthening science education in Nigeria, empirical data continue to indicate suboptimal academic performance in Biology, a core subject underpinning scientific and health-related career pathways (WAEC, 2023; Yusuf & Daramola, 2021). This persistent low achievement, particularly prevalent in public secondary schools, is frequently attributed to the continued reliance on conventional lecture-based pedagogies that emphasize rote memorization over conceptual understanding and higher-order thinking skills. In response to global shifts toward technology-enhanced learning, Artificial Intelligence (AI)-based instructional systems have emerged as potential pedagogical innovations capable of delivering adaptive, personalized, and interactive learning experiences.

However, within the Nigerian educational context, rigorous empirical investigations assessing the instructional efficacy of AI-based learning systems in comparison to traditional teaching methods remain scarce. This gap in the literature necessitates systematic evaluation of AI-based pedagogical interventions to determine their impact on students' cognitive performance and learning outcomes in Biology at the senior secondary school level.

Objective of the Study

The study was guided by the following objective:

1. To examine the impact of AI-based learning systems on the academic performance of senior secondary school students in Biology against the traditional **lecture method** in Katsina state.

Research Question

1. What is the impact of AI-based learning systems on the academic performance of senior secondary school students in Biology against the traditional lecture method in Katsina state?

Hypothesis

1. There is no significant difference in the academic performance of senior secondary school students taught Biology using AI-based learning systems and those taught using the traditional lecture method in Katsina state.

Methodology

This study employed a **quasi-experimental research design,** specifically the *non-equivalent pre-test, post-test experimental and control group design*. The population of this study comprises all senior secondary school (SSS II) students in the public and private secondary schools within Katsina local government area of Katsina state, Nigeria. According to data obtained from the Katsina State Ministry of Education (2024), there are 30 registered secondary schools (both public and private) in the LGA. These schools collectively serve as student population totaling to 8,206 students. To ensure a representative and unbiased selection of participants, the study employed a stratified random sampling technique. This method is ideal for educational research where the population consists of naturally occurring subgroups (school type, gender, and location), and it allows for proportional representation from different categories within the study area (Fraenkel, Wallen, & Hyun, 2012). By stratifying the sample along these dimensions, the study aims to control for possible confounding variables and enhance the generalizability of the findings to the wider student population in Katsina LGA. Two schools and one intact class in each with 150 students were selected as sample.

The study employed the AI-Based Biology Instructional Assessment (AIBBIA), which is an instrument specifically designed to measure **students' academic performance on AI-based instructional methods in learning Biology.** The instrument was subjected to expert validation. Specialists in Biology education and educational measurement reviewed the instrument for content and construct validity. Pearson Product-Moment Correlation was used to analyze the test-re-test scores which yielded a reliability coefficient **of 0.78**, indicating an acceptable level of reliability. The research question was answered using mean and standard deviation **while, independent samples t-test** was used to test the hypothesis at 0.05 alpha level.

Results

Research question one: What is the impact of AI-based learning systems on the academic performance of senior secondary school students in Biology against the traditional lecture method?

Table 1: Mean and standard deviation of experimental and control groups

Group	N	Mean (M)	Standard Deviation (SD)	Mean Difference (MD)
Experimental	75	76.21	8.12	
				18.03
Control	75	58.18	7.45	

Table 1 revealed that students at the experimental group taught Biology using AI-based learning systems has mean score of 76.21 and standard deviation of 8.12 while those at the control group taught using traditional lecture method had mean score of 58.18 and standard deviation of 7.45, accordingly. Mean difference of 18.03 was calculated in favor of the experimental group. This implies that students taught using AI-based learning system performed better than those taught using lecture method.

Hypothesis: There is no significant difference in Biology academic performance between students taught using AI-based learning systems and those taught using traditional lecture method.

Table 2: Independent samples t-test of the experimental and control groups

Group	N	Mean	Standard Deviation	df	t-cal	t-crit	p-value
Experimental	75	76.21	8.12				
				148	7.56	2.68	0.001
Control	75	58.18	7.45				

Table 2 displayed t-test analysis of significant difference between students taught using AI-based learning system and those taught using traditional lecture method. Result of the analysis indicated that the p-value =0.001 is less than the alpha 0.05. The t-calculated 7.561 is greater than the t-critical 2.68 at degree of freedom of 148. The hypothesis which stated that there is no significant difference in Biology academic performance between students taught using AI-based learning systems and those taught using traditional lecture method is rejected. This implies that there is a significant difference in academic performance of students taught using AI-based learning system and those taught using lecture method. The difference is in favor of students taught using AI-based learning system. P-value=0.001<alpha=0.05.

Discussions of Findings

This study investigated the impact of Artificial Intelligence (AI)-based learning systems on students' academic performance in Biology in senior secondary schools in Katsina Local Government Area, Katsina State, Nigeria. The findings were based on one research question and one hypothesis tested using independent samples t-tests. The analysis revealed a statistically significant difference in post-test scores between the experimental and control groups. Students exposed to AI-based learning recorded better academic performance than those exposed to traditional lecture method. This finding is consistent with the findings of **Luckin et al. (2016)** that AI-based learning system has the potential to transform education by personalizing learning experiences and improving outcomes. Similarly, the findings also agrees with the findings of **Holmes et al. (2019)** which revealed that AI-based instruction systems significantly improved science achievement among secondary students by offering real-time visualization tools.

In addition, this study finding is in line with previous studies suggesting that the integration of artificial intelligence (AI) in education improves student learning outcomes (Zawacki-Richter et al., 2019; Chen et al., 2020). AI-based learning environments offer adaptive feedback, personalized instruction, and interactive resources, all of which help foster deeper understanding and academic engagement. These features are particularly beneficial in subjects like Biology, which require visualization of abstract concepts and dynamic systems.

This finding aligns with **Mayer's Cognitive Theory of Multimedia Learning (2005)** which posits that learning is more effective when learners can process information through multiple channels (visual and auditory), as is often the case with AI-based learning environments. AI tools such as simulations, intelligent tutors, and educational games help solidify abstract biological concepts, leading to improved academic performance.

Conclusion

This study concluded that students who were taught using AI-supported instruction outperformed those taught with traditional lecture method. The study therefore added that AI-based learning systems play a critical role in transforming science education in Nigeria. When thoughtfully implemented, these systems can bridge gaps in instructional quality, foster personalized learning, and improve students' mastery and academic performance of complex scientific concepts in Biology.

Recommendations

Based on the findings and conclusion of the study, the following recommendations were made:

1. The Federal and State Ministries of Education should consider integrating AI-based learning systems into the senior secondary school Biology curriculum. This will ensure that students benefit from personalized, interactive, and technologically enhanced instruction.
2. Teachers should be trained on how to use AI tools effectively in the classroom. Continuous professional development programs should be introduced to build teacher competence in digital pedagogy and the use of AI in instruction.

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