

# HARNESSING AI TUTORS FOR ENHANCING INTERACTIVE BIOLOGY LEARNING AMONG SECONDARY SCHOOL STUDENTS IN NIGER STATE.

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## Abstract

*The rapid advancement of Artificial Intelligence (AI) presents unprecedented opportunities to transform science education in Nigeria. This paper explores and advocate for the adoption of AI tutors in promoting interactive biology learning among secondary school students in Niger State. Biology, with its abstract concepts ranging from cellular structures to complex organ systems, often challenges student's comprehension when taught through traditional methods. AI tutors, equipped with adaptive learning algorithms, interactive simulations, and personalized feedback mechanisms, offer a pathway to more engaging and effective instruction. This paper positions AI tutors not merely as experimental tools but as catalysts for educational innovation. It highlights their potential to enhance student engagement, improve retention of biological concepts, and democratize access to quality learning experiences. At the same time, it acknowledges challenges such as infrastructural limitations, teacher preparedness, and equity gaps between urban and rural schools. Based on the main insights found in the literature, this paper strongly recommend the creation of solid policy frameworks, focused teachers capacity building programmes and thoughtful curriculum integration to ensure effective and lasting use of AI tutors in Nigeria.*

**Keywords:** Artificial Intelligence (AI), AI Tutor, Interactive learning, Biology education, Secondary schools.

## Introduction

Science is a comprehensive and methodological study of the natural world that uses observation and reasoning to describe and predict phenomena in order to understand and solve pressing issues that face humanity (Joseph, 2026). Science is the underpinning of all societal progress and innovations that stem from the advancement of technologies. In today's world, the rapid advancement of Artificial Intelligence (AI) has increased the scope and application of science. Artificial Intelligence (AI) enables computers and machines to replicate many cognitive functions that characterize and distinguish human beings, including learning, reasoning, and decision-making. The development and advancement of Artificial Intelligence (AI) is a direct result of science and the integration of several fields of study including computer science, mathematics, and biology, as well as the natural and social sciences. The rapid advancement of Artificial Intelligence (AI) has transformed various aspects of our lives, particularly in education. As a result, educators and researchers are diving deeper into AI-driven innovations to tackle ongoing challenges in teaching and learning across different subjects. Notably, biology emerges as one of the subjects where AI-powered instructional tools can greatly boost students' grasp of concepts, their engagement, and overall academic success.

Biology is a complex subject that requires students to understand a great deal of information about the interaction between living organisms and their environment (Ajibike, 2025). Biology is a science subject offered in most senior secondary schools in Nigeria, and serves as opened pathway to careers in medicine, agriculture, biotechnology and environmental science. The National Policy on Education (NPE, 2013), clearly stated in its Biology curriculum that the subject is meant to equip learners with relevant and meaningful knowledge, and to acquire the ability to apply scientific knowledge to everyday life. Biology education in particular can benefit from AI integration, as it can enhance student learning outcomes, improves

engagement and develop essential skills for digital era. As such, biology education must adapt to changes due to new discoveries and advancements and provide students with the skills and knowledge necessary to succeed in the subject (Ajibike, 2025).

### **Statement of the Problem**

Biology is one of the most important science subjects in Nigerian secondary schools and serves as a foundation for careers in medicine, agriculture, biotechnology, and environmental sciences. Despite its importance, many students experience difficulties in understanding abstract and complex biological concepts such as cellular structures, genetics, physiology and ecological interactions. Traditional teaching methods, characterized by chalkboard instruction, rote memorization, and teacher-centered approaches, often fail to stimulate students' curiosity, active participation, and deep conceptual understanding (Joseph, 2026).

Furthermore, inadequate laboratory facilities, shortage of qualified teachers, and limited opportunities for personalized learning continue to hinder effective biology instruction in many schools in Niger State. Consequently, students' engagement and achievement in biology remain below expectations. This had been shown in West African Examinations Council (WAEC) Chief Examiners' Reports from 2018 to 2023 and numerous scholarly studies such as (Oyovwi, 2024). The emergence of AI tutors offers innovative opportunities for personalized, interactive, and adaptive learning experience. However, their adoptions in secondary schools in Nigeria remains limited due to infrastructural deficits, teachers preparedness issues, financial or funding constraints, and digital inequality. Therefore, there is a need to explore how AI tutors can be harnessed to enhance interactive Biology learning among secondary school students in Niger State.

### **Purpose of the Paper**

The major purpose of this paper is to examine the potential of Artificial Intelligence (AI) tutors in enhancing interactive biology

learning among secondary school students in Niger State, and in extension, Nigeria as a whole. The objectives of this study include:

- (i) Examine the concept and role of Artificial Intelligence (AI) in biology education
- (ii) Explore the opportunities of AI tutors for enhancing interactive biology learning among secondary school students in Niger State.
- (iii) Identify the challenges associated with the implementation of AI tutors in secondary schools in Niger State.
- (iv) Recommend policy strategies for effective implementation.

### **Theoretical Framework**

This paper is anchored on two (2) relevant theories, and they are:

- (i) The Constructivist Learning Theory, and
- (ii) The Connectivism Theory. Both of these theories provide a convincing framework for this study.

#### **(i). Constructivist Learning Theory**

Constructivist theory was propounded by Piaget and further developed by Vygotsky in 1978. The theory suggests that learners construct knowledge actively through experience, exploration and interaction with their surroundings, rather than passively receiving information. In other words, learning takes place when students engage in meaningful activities, explore new ideas, and link fresh information to what they already know. AI powered Biology tools enhance constructivist learning by allowing students to explore biological concepts through simulations, virtual experiments, and inquiry-based activities. This approach turns students into active explorers instead of mere passive recipients of information.

#### **(ii). Connectivism Theory**

This theory was proposed by Siemens (2005), he highlights the importance of learning through digital network and interactions facilitated by technology. It acknowledges that knowledge is spread across various networks, and learners need to improve their skills to access, evaluate, and utilize information from diverse sources. AI technologies relate with connectivist ideas by linking students to extensive knowledge bases, smart tutoring systems, and

collaborative learning platforms that deepen their understanding of science.

## **Methodology**

### **Research Design**

This study employed a qualitative conceptual research design, strengthened through an integrative survey and critical analysis of existing literature. This approach proved appropriate as the goal was to gain a deep understanding of how Artificial Intelligence (AI) tutors can enhance interactive Biology learning for secondary school students, instead of gathering fresh empirical evidence. Thus, the research was anchored within established texts or literatures, focusing on functions, uses, potentials, and challenges of AI tutors in the context of Biology education.

Data for this study were sourced exclusively from secondary materials such as peer-reviewed journals, monographs, conference proceedings, official policies and credible works related to AI within schooling, intelligent tutoring systems, interactive learning, and Biology education. The information gathered from these sources was systematically reviewed, extracted, and organized around the key concepts and objectives of the study.

The analysis of the reviewed literature employed thematic content analysis and narrative synthesis. Major ideas, findings, and arguments were identified, categorized, and structured into distinct categories regarding AI tutors, personalized learning, immediate feedback, support for challenging Biology concepts, and the hurdles of AI adoption. Findings from various sources were compared and synthesized to ensure consistency and credibility, while following ethical norms for accurate referencing, objective representation, and the avoidance of plagiarism. The study therefore provides a foundation for subsequent empirical investigations that may examine the actual effectiveness, level of utilisation, challenges and learning outcomes associated with the use of AI tutors among secondary school students.

## **Literature Review**

### **Concept of Artificial Intelligence (AI)**

Information technologies, particularly artificial intelligence (AI), are revolutionizing modern education (Wang *et al* 2024). AI is the science of making machines performs tasks that usually require a human brain such as understanding spoken language, recognizing patterns in a biological diagram, or making complex decisions based on vast amounts of data. In the classroom, AI is not just one single tool; it is a multifaceted ecosystem (Russell & Norvig, 2020). AI is a subfield of computer science dedicated to understanding human thought processes and recreating their effects through information systems. AI is a subfield of computer science dedicated to understanding human thought processes and recreating their effects through information systems. The primary goal of AI is to create intelligent systems (i.e. computer programs or machines) that are capable of intelligent behaviors, including learning, reasoning, problem-solving, perception, and creating. Typical examples of AI technologies include expert systems, neural networks (including machine learning and deep learning techniques), fuzzy logic, genetic algorithms, and intelligent agents (Wang *et al.* 2024). Scholars often distinguish between strong and weak AI (Wells, 2023). Strong AI, also known as artificial general intelligence, possesses a broad spectrum of human capabilities, including communication, reasoning, and emotional responses, and is capable of multiple tasks. In contrast, weak AI, also known as narrow AI, does not possess a full array of human capabilities but can use algorithms to solve problems or reason for specific tasks, such as fraud detection and chess playing. AI applications that have been currently developed and brought into commercial use are categorized as weak AI. Generative Artificial Intelligence (GenAI) refers to technologies that create new content by interpreting patterns in raw materials such as text, images, audio, and video. These technologies utilise advanced machine learning techniques, including deep learning and neural networks, to generate outputs that reflect human imagination and intelligence. Within this category, large language models (LLMs), such as GPT and BERT, are a major subset of GenAI. They play an especially significant role

because of their capacity to process and generate human language (Wang *et al.*, 2024).

In various sectors, including education, AI has made a significant contribution in improving the efficiency and effectiveness of the learning process (Fitri & Dilia, 2024). In the field of biology, which has material complexity and various abstract concepts, AI offers various innovative solutions that can improve the quality of learning. Biology learning often involves a deep understanding of the structure, function, and interactions of living organisms (Lasaiba, 2023). According to Usak, (2024), Artificial Intelligence in biology education can be defined as the deployment of AI in sections o study that help learners and researchers in their areas of concentration, specifically biological sciences. The use of AI technology can help students understand complex material through visualization, simulation, and personalization of the learning process. For example, AI-based technology can create three-dimensional (3D) models of the structure of human cells or organs, allowing students to learn the material in a more interactive way (Telaumbanua, 2025)

### **Concept of AI Tutors**

#### **What is an AI Tutor?**

An AI tutor is a virtual teaching assistant or a smart software that teaches or guides and help students learn at their own pace. It is powered by Artificial Intelligence and uses the latest technologies like machine learning and natural Language processing to tailor lessons to student's needs. It helps students learn by breaking down topics, personalize lessons and provide instant feedback to students. The assistance provided by AI tutors is always available 24/7, and never gets tired of explaining things. Generally, it makes learning faster, easier and more convenient than ever. Recent systematic literature reviews and studies highlight that AI tutors and intelligent tutoring systems (ITS) in biology education significantly improve student comprehension, boost academic achievements, and optimize cognitive load by breaking down complex processes like cell division

and photosynthesis (Aripin *et al.* 2024). Unlike old fashioned computer programs that simply provide a "Correct" or "Incorrect" mark, an AI tutor actually analyzes the student's logical journey and thought process.

It functions through three core architectural models, as identified by Luckin, Holmes, Griffiths, & Forcier (2016):

- (i) The Domain Model: This is the knowledge base of the AI. For this research, it represents a master level understanding of the Nigerian Biology curriculum, including the West African Senior School Certificate Examination (WASSCE) standards.
- (ii) The Student Model: This is the most crucial part. The AI tracks what the student knows, what they frequently forget, and even their level of emotional engagement or frustration.
- (iii) The Pedagogical Model: This is the "teacher" component of the software. It decides the optimal time to give a hint, when to provide a harder challenge, and when to pause for a review session.

This creates a process called "scaffolding." Just like a builder uses a temporary scaffold to reach higher parts of a structure, the AI tutor provides hints and support to help the student reach a higher level of cognitive understanding. As the student gets stronger in Biology concepts, the AI slowly pulls back that support, leading to true intellectual mastery (Mousavinasab, Zarghi, Rakic, & Mohammadi, 2021).

### **Opportunities of AI Tutors in Biology Education**

Biology is a beautiful but difficult subject because so much of it happens at a level we cannot see with the naked eye, such as inside a microscopic cell or across a massive, invisible ecosystem. For secondary school students, AI tutors in biology education offer transformative opportunities by providing 24/7 personalized learning, adaptive scaffolding, and real-time concept clarification.

Recent education journals emphasize that these tools democratize access to interactive science experiments, effectively compensating for inadequate physical laboratory facilities in many regions. AI tutors open doors that were previously locked by a lack of physical resources in the following ways:

1. Seeing the Invisible: AI tutors assist students and teachers in viewing the invisible biological processes and provide clarity on many concepts that proved difficult to understand. Many biological processes, like the Krebs cycle or DNA replication, are just abstract words on a page in a textbook. AI tutors can generate dynamic 3D models and animations that allow a student to virtually walk through a cell, making the invisible visible and much easier to remember (Luckin, Holmes, Griffiths, & Forcier, 2016).
2. A Lab in Every Pocket (Virtual Biology Labs.): Most secondary schools in this part of the world, especially in Nigeria, are not adequately provided with physical laboratories, neither stocked with expensive microscopes and volatile chemicals. In the event of this, AI tutors provide Virtual Dry Labs., which enables students to conduct biological experiments in a virtual environment, overcoming challenges related to inadequate laboratory facilities. A student in a rural village can perform a virtual dissection or simulate a cross breeding experiment in genetics without needing a single physical tool. AI tutors, through simulation can also model complex biological processes such as mitosis, enzyme reactions and so on, offering students a hands-on experience even in resource-limited settings (Ozioko, Ibrahim, Anita-Ugwu, 2025)
3. Breaking the Language Barrier: English is the language of instruction in all secondary schools in Nigeria, but it is not always the language of the heart. This has become a great challenge when it comes to grasping important biological terms and processes. Advanced AI tutors can help translate

complex biological terms into simpler English or local contexts, aiding comprehension so that a student does not fall behind simply because of a vocabulary gap (Aina & Ayodele, 2018).

4. Empowering the Teacher: Nigeria currently faces a massive teacher to student ratio. When an AI tutor handles the repetitive work such as grading basic quizzes or explaining the parts of a leaf for the tenth time, the human teacher is freed up to do what they do best which is mentoring students, leading deep discussions, and focusing on practical experiments.
5. Real-Time Feedback and Assessment: AI tutors provide AI-based grading systems, evaluate student performance, offer real-time feedback and also provide detailed insights into students' strengths and weaknesses. This system can mark assignments, quizzes, and even essay-based responses, ensuring that students receive timely evaluations without overburdening teachers (Ozioko *et al*, 2025)

### **Challenges of Implementing AI-Tutors in Biology Education in Nigeria Classrooms**

We must be honest about the ground reality in Nigeria. Some of the challenges of implementing AI tutors generally in Nigerian secondary schools are as follows:

1. Resistance to Technological Change: Despite the potential opportunities and benefits of AI and AI tutors, some educators, parents and policymakers remain skeptical about its effectiveness in education. Fear of job displacement, distrust in AI's decision making process, and reluctance to shift from traditional teaching methods contribute to resistance against AI adoption. (Ozioko, *et al*, 2025).
2. The Power and Data Struggle: Many Nigerian secondary

schools, especially those in the rural areas lack the necessary infrastructures to support AI-based education. You cannot run a high level AI tutor without consistent electricity or reliable internet connectivity and absence of modern computer facilities. The National Grid issues and the high cost of internet data in Nigeria are the biggest barriers. If a student in a rural area cannot charge their device or afford a data bundle, the best AI tutor in the world becomes useless to such student or community (Adedoyin & Soykan, 2020, Ozioko *et al*, 2025).

3. The Cost of Entry: Even though smartphones are becoming common, the high performance devices needed to run smooth AI simulations are still too expensive for many families in low income brackets (Ezema, Ugwuanyi, & Okeke, 2021).
4. Teacher Training and Readiness: The level of readiness of teachers to adopt and integrate AI in biology education across Nigeria is very discouraging. Many of these teachers lacks the necessary skills to use the AI tutors and training programmes on digital pedagogy and therefore are believed to naturally develop fear (Technophobia) for what they did not understand (Ozioko *et al.*, 2025). Many veteran teachers in Nigeria feel overwhelmed by new technology or worry that a machine will eventually replace them. Without proper training and reassurance, these teachers may see AI as a threat rather than a helpful tool (Owolabi, Oyewole, & Okebukola, 2023).
5. Financial Constraints: It is obvious that in Nigeria the acquisition, implementation and maintenance of AI-powered educational tools such as computers, digital platforms and hardwares e.g. smartboards and VR headsets require a huge financial investment. Many secondary schools in Nigeria operate under tight budgets and struggle to afford high-tech

learning solutions. This financial constraint is one of the major challenge faced by educators, students and every other stakeholders in education.

### **Use of AI Tutors in Nigeria Classrooms**

The integration of artificial intelligence (AI) tools in the educational process marks a revolutionary shift in pedagogical approaches and learning strategies (Chen et al., 2020). AI tools are now a valuable resource for assisting with diverse inquiries, ranging from simple factual questions to complex problem-solving scenarios (Tedre et al., 2021). The forefront of this technological revolution is led by tools such as OpenAI's ChatGPT and Google Bard. These models illustrate significant advancements in the field of natural language processing, reflecting the ongoing evolution in the way machines comprehend and interact using human language. Developed by OpenAI, ChatGPT is known for its ability to generate human-like text and engage in interactive conversations across a wide range of topics. ChatGPT 4 enhances its predecessor, ChatGPT 3.5, with superior contextual comprehension and precision in responses (Johansson, 2023).

Currently, the educational sector in Nigeria is in the "Early Adopter" phase. In urban centers like in the State Capitals, there is increasing number of students using apps like U-lesson, SimbiBot, or Gradely. These are the pioneers of the movement. They use AI to recommend videos and practice questions based on how the student performed in previous sessions. Intelligent Tutoring Systems (ITS) have emerged as a highly effective modality for delivering personalized instruction. Globally, research demonstrates that AI-driven tutors such as adaptive platforms can significantly outperform traditional learning methods in terms of student achievement. In Nigeria, a survey involving 298 final-year students from two Colleges of Education in Lagos State found that those using an AI-powered tutoring system exhibited significantly higher English proficiency than their peers relying on traditional teaching methods (Adedokun & Olabode, 2024). However, for the majority of students in the public schools, AI integration is still an aspiration. Some teachers are starting to use General AI like ChatGPT to help them write lesson plans or create test

questions, but this is fundamentally different from a dedicated AI tutor that actually walks a student through a lesson step by step (UNESCO, 2023). We are seeing a Digital Divide where students in private schools are getting a massive head start because they have access to these tools, while public school students are left with traditional, less interactive methods.

### **Implications for the Use of AI Tutors in Nigerian Classrooms**

If we want this technological revolution to work for all secondary schools in Nigeria, rather than just the wealthy, a strategic plan is required:

1. **Investing in Smart Infrastructure:** We cannot wait for the national grid to stabilize. Niger State should look at solar powered computer hubs in schools. We also need offline first AI which are tools that you can download once and then use without a constant internet connection.
2. **Teaching the Teachers:** We do not need teachers to be computer scientists; we need them to be AI Facilitators. They need to know how to use the data the AI provides to help their students more effectively (Owolabi et al., 2023).
3. **Making it ours:** The Biology examples in the AI should be Nigerian. Instead of talking about an oak tree, the AI should talk about a Baobab or a Shea butter tree. Using the local flora and fauna of the Kainji Lake National Park makes the science feel real and relevant to a student in Nigeria.
4. **Focusing on Fairness:** The government must step in to ensure that a student in a remote village has the same digital opportunities as a student in the capital. This might mean subsidized learning tablets or zero rated educational data for specific academic platforms.

### **Key Insights from the Literature**

The main insights found in the literature revealed that:

1. **AI Tutors Enhance Understanding of Abstract Concepts:** AI

tutors help students visualize difficult biology concepts through simulations, animations and 3D models, thereby improving comprehension and retention.

2. **AI Tutors Promote Personalized Learning:** AI systems adapt lessons to individual learning needs, allowing students to learn at their own pace while receiving customized feedback and support.
3. **AI Tutors Provide Virtual Laboratory Experience:** AI-powered virtual laboratories enable students to conduct experiments even in schools with inadequate laboratory facilities.
4. **AI Tutors Improve Students Engagement:** Interactive learning environments created by AI tutors increase students' participation, motivation, and interest in biology learning.
5. **AI Tutors Support Teachers:** AI tutors reduce teachers work load by assisting with grading, assessment feedback provision, and repetitive instructional tasks, allowing teachers to focus more on monitoring and practical activities.
6. **Major Challenges Exist:** The implementation of AI tutors in Niger State schools is constraint by – poor electricity supply, inadequate internet connectivity, High cost of digital devices, financial limitations, insufficient teacher training, and resistance to technological changes.
7. **Persistence of Digital Inequality:** The study found that AI adoption is more common in urban and private schools, creating a digital divide between privileged and less privileged learners.
8. **Government Intervention Required for Successful Adoption:** The study emphasized the need for improved ICT infrastructure in secondary schools, teacher capacity building, curriculum reforms, equitable access policies, and

increased funding for AI-driven educational technologies in secondary schools.

### Conclusion

Introducing AI tutors into secondary school biology can change science teaching in Nigeria. AI tutors can help reduce teacher-students gaps in learning and level the playing field for students. This study therefore concluded that AI tutors have significant potential to transform biology education in Niger State by making learning more interactive, personalized, and effective. However, the realization of these benefits depends on addressing infrastructural, financial, and capacity building challenges through co-ordinated efforts by the government and educational stakeholders. This paper in a nut shell calls for a paradigm shift – moving away from conventional or traditional teaching strategies to a more interactive learning approach driven by AI technology in the Nigeria education system,

### Recommendations:

1. Government and all education stakeholders should massively invest in educational infrastructures by making providing electricity, internet connectivity, computers and other affordable digital devices to secondary schools in Nigeria.
2. Government and other stakeholders should focus more on continuous training and development of teachers to help integrate AI tutors in teaching biology in Nigerian secondary schools.
3. Curriculum planners should adjust the biology syllabus to include AI modules for difficult topics like developmental /cell biology, genetics, ecology and physiology.
4. Government and education policy makers should take drastic equity measures to ensure that schools especially those in the rural communities are prioritized to promote equity with the AI tutors.
5. Educators and education implementers should embark on public awareness campaigns focusing on changing the ideas of the parents and some educators to better understanding on how AI tutors are complementary and not a replacement of teachers.
6. Educational researchers should be encourage to extend their studies of AI tutors beyond and other STEM subjects to help build a better understanding of how the AI constructs impact science.

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