



Artificial Intelligence as Emerging Tool in Teaching and Learning of Biology in Senior Secondary Schools in Gumel Local Government Area, Jigawa State

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Abstract

Artificial Intelligence (AI) has emerged as a transformative force across various sectors, with education being one of the key areas experiencing significant change. The integration of AI into teaching and learning, particularly in science education, is reshaping traditional instructional methodologies and enhancing student engagement. This paper examined the impact of AI in the teaching and learning of Biology in senior secondary schools within Gumel Local Government Area, Jigawa State. It explored AI-powered instructional tools, virtual Biology labs, automated assessment systems, and the role of AI in fostering scientific inquiry and critical thinking among students. The study highlighted the numerous benefits of AI, including personalized learning experiences, improved student comprehension, enhanced accessibility to educational resources, and reduced workload for teachers. However, the paper also addressed significant challenges such as inadequate infrastructure, limited teacher readiness, financial constraints, and ethical concerns surrounding AI use in education. Through an analysis of global case studies of AI implementation in science education, the study draws lesson that can be applied to the Nigerian educational landscape. Furthermore, it provides policy recommendations for successful AI integration into Biology education in Nigeria. The final section of the paper explored the prospects of AI in Biology education, emphasizing its potential to revolutionize learning experiences, bridge educational gaps, and contribute to scientific advancements.

Keywords: Biology, Artificial Intelligence & AI technologies.

Introduction

Artificial Intelligence (AI) is revolutionizing various industries, with education standing out as one of the most affected sectors. Artificial Intelligence's potential in education lies in its ability to transform traditional teaching methods into more interactive, engaging, and effective learning experiences. John McCarthy in 1955, coined the term AI he defined Artificial Intelligence as the science and engineering of making intelligent machines, especially intelligent computer programs Biology is a complex subject that requires students to understand intricate biological processes, conduct laboratory experiments, and develop analytical skills. Traditional classroom-based teaching methods, often reliant on textbooks and lectures, sometimes fail to fully engage students or provide them with hands-on learning experiences. AI introduces innovative solutions such as adaptive learning systems, virtual simulations, and automated assessment tools that cater to students' individual learning needs.

In Nigeria, particularly in Gumel Local Government Area, Jigawa State, the conventional

methods of teaching Biology face multiple challenges, including inadequate laboratory facilities, teacher shortages, and limited access to up-to-date learning resources. Many schools in the region lack modern laboratory equipment, making it difficult for students to conduct necessary experiments. AI-based learning tools offer potential solutions to these challenges by providing interactive simulations, virtual biology labs, AI-driven tutoring, and real-time performance tracking. This paper explores how AI is transforming the learning process in senior secondary schools, analyzing the benefits, challenges, and implications of AI integration in Biology education. It aims to contribute to the ongoing discussion on AI adoption in education by presenting recommendations for policymakers, educators, and stakeholders on how to effectively harness AI to improve Biology instruction in Nigerian secondary schools.

Understanding Artificial Intelligence in Education

Artificial Intelligence refers to the development of computer systems that can perform

tasks that typically require human intelligence, including reasoning, learning, problem-solving, perception, and decision-making. AI technologies leverage algorithms and vast amounts of data to replicate cognitive functions, making them capable of adapting to new inputs and improving over time. In the context of education, AI is revolutionizing traditional learning methods, providing personalized instruction, and automating various aspects of the teaching process. Some authors who defined AI, include: John McCarthy in 1955, coined the term AI he defined Artificial Intelligence as the science and engineering of making intelligent machines, especially intelligent computer programs. Also, Elaine Rich in 1983 focusing on the comparative ability with human stated that "AI is the study of how to make computers do things which at the moment, people do better." Hence, Artificial intelligence is a machine which aims at making human life and activities easier by analyzing data and information faster.

Types of AI Technologies Used in Education

Several AI-driven technologies are being implemented in the education sector, each playing a unique role in improving the learning experience:

- **Machine Learning (ML):** AI systems analyze student performance data to tailor instructional content, identify learning gaps, and predict learning outcomes. This helps educators design targeted interventions for struggling students. (Luckin, 2018)
- **Natural Language Processing (NLP):** Used in AI-powered chatbots and virtual assistants to facilitate student learning, answer questions, and provide explanations in real time. (Luckin, 2018)
- **Computer Vision:** Helps create interactive learning experiences, including virtual biology labs that simulate experiments and biological observations, allowing students to visualize cell structures and physiological processes. (Luckin, 2018)
- **Virtual Reality (VR) and Augmented Reality (AR):** These technologies offer immersive learning experiences that enable students to interact with 3D models of biological structures, such as the human body or ecological systems, making abstract concepts easier to understand. (Luckin, 2018)
- **Automated Assessment Systems:** AI-powered grading tools assist in evaluating student

assignments, providing immediate feedback, and tracking academic progress over time, thereby reducing teachers' workload.

- **Data Analytics and Predictive Modeling:** AI can analyze large datasets of student performance, identifying patterns that help educators improve curriculum design and teaching strategies.

By leveraging these AI technologies, educators can create dynamic, adaptive, and student-centered learning environments. AI ensures that students receive real-time support, reduces the administrative burden on teachers, and enables institutions to optimize educational resources efficiently.

Additionally, AI's ability to analyze vast amounts of data enhances decision-making processes within schools, helping educators track student progress, identify at-risk learners, and implement early interventions. This data-driven approach enhances educational outcomes, ensuring that students receive the guidance and support they need to succeed in their studies.

AI Applications in Biology Teaching And Learning

In recent years, Artificial Intelligence (AI) has emerged as a transformative force across diverse fields, and education is no exception. In the realm of biology teaching and learning, AI offers powerful tools to enhance instruction, personalize student experiences, and foster deeper understanding of complex biological concepts. From intelligent tutoring systems to virtual laboratories and adaptive assessment platforms, AI is reshaping how biology is taught, learned, and experienced (Chen, Xie, & Hwang, 2020)

1. **AI-Powered Instructional Tools:** Smart tutoring systems provide students with instant feedback and adaptive learning experiences, allowing them to master Biology concepts at their own pace. These tools can customize lesson plans to fit individual student needs, ensuring that difficult topics are revisited until mastery is achieved.
2. **Virtual Biology Labs:** AI-driven simulations enable students to conduct biological experiments in a virtual environment, overcoming challenges related to inadequate laboratory facilities. These simulations can model complex biological processes such as mitosis, enzyme reactions, and ecological interactions, offering students a hands-on experience even in resource-limited settings.

3. **Automated Assessment and Feedback:** AI-based grading systems evaluate student performance, offer real-time feedback, and provide detailed insights into student strengths and weaknesses. These systems can mark assignments, quizzes, and even essay-based responses, ensuring that students receive timely evaluations without overburdening teachers.
4. **Gamification and Student Engagement:** AI-driven educational games integrate interactive elements such as quizzes, animations, and rewards to make Biology learning more engaging and enjoyable. These games make learning fun, boost student motivation, and encourage active participation in lessons.
5. **AI-Driven Research and Data Analysis:** AI assists students in analyzing biological data, generating reports, and improving their scientific inquiry and research skills. This can be particularly useful in conducting experiments, tracking biodiversity, or studying genetic variations in Biology projects.
6. **Real-Time Feedback and Assessment:** AI-based assessment tools provide immediate feedback, helping students identify and rectify mistakes quickly, leading to better learning outcomes.
7. **Enhanced Research Capabilities:** AI assists students and teachers in analyzing biological data, conducting scientific research, and drawing meaningful conclusions from complex datasets.
8. **Support for Students with Disabilities:** AI-powered assistive technologies, such as speech-to-text tools and interactive learning apps, provide inclusive education opportunities for students with special needs.

Practical Application of AI to Biology Education in Gumel Local Government Area

To tailor AI solutions to the specific educational landscape of Gumel Local Government Area, several practical applications can be implemented:

1. **Personalized Learning:** AI enables adaptive learning platforms that tailor instruction to individual student needs, helping them grasp Biology concepts at their own pace.
2. **Enhanced Student Engagement:** AI-driven tools such as gamified learning apps, virtual simulations, and AI tutors make Biology lessons more interactive and interesting.
3. **Improved Understanding of Complex Concepts:** Virtual labs and AI-generated 3D models help students visualize abstract biological processes such as photosynthesis, cellular respiration, and DNA replication.
4. **Accessibility to Quality Education:** AI-powered digital platforms offer remote learning opportunities, allowing students in resource-limited areas to access quality Biology education.
5. **Reduction in Teacher Workload:** AI automates tasks such as grading assignments and quizzes, allowing teachers to focus on interactive and in-depth teaching.
1. **AI-Powered Virtual Labs:** Given the limited availability of physical laboratory resources, schools in Gumel can benefit from AI-driven virtual labs. These platforms allow students to conduct experiments in a simulated environment, improving their practical understanding of Biology concepts without the need for expensive laboratory equipment.
2. **AI-Based Adaptive Learning Systems:** AI-powered platforms can provide personalized learning experiences by analyzing student performance and adjusting Biology lessons accordingly. This helps teachers identify struggling students and offer targeted support to improve comprehension.
3. **AI-Assisted Language Translation Tools:** In regions where students face language barriers, AI-driven translation tools can bridge communication gaps by translating complex Biology concepts into local dialects, enhancing understanding and engagement.
4. **Automated Assessment Tools:** AI can assist in grading assignments, tracking student progress, and providing real-time feedback, reducing teachers' workload and improving efficiency in evaluating student performance.

Benefits of AI in Biology Education

Artificial Intelligence (AI) enhances biology education by personalizing learning, improving engagement, and simplifying complex topics. It offers faster feedback, adaptive resources, and new ways to explore biological concepts.

5. **Teacher Training on AI Utilization:** Schools in Gumel should prioritize teacher training programs on AI integration, ensuring educators can effectively use AI tools in their classrooms and guide students in leveraging AI-based learning resources.

By implementing these AI-driven solutions, secondary schools in Gumel Local Government Area can enhance the quality of Biology education, ensuring students receive engaging, technology-enhanced learning experiences despite existing infrastructural limitations.

Challenges of Implementing AI in Biology Education

Infrastructure Limitations

Many Nigerian schools, especially those in rural areas like Gumel Local Government Area, lack the necessary infrastructure to support AI-based education. Reliable internet connectivity, stable electricity supply, and modern computer facilities are essential for AI implementation, yet they remain scarce in many schools. Without these fundamental resources, AI-driven tools such as virtual labs, adaptive learning systems, and automated assessments cannot function effectively. Addressing these infrastructural challenges requires significant investment in digital infrastructure, government support, and partnerships with technology providers.

Teacher Training and Readiness

The successful integration of AI in Biology education depends on the preparedness of teachers to adopt and implement AI-based teaching methodologies. Many educators lack the necessary skills to use AI-driven tools, and training programs on digital pedagogy are limited. Teachers must receive extensive professional development on how to integrate AI into their lesson plans, interpret AI-generated insights, and guide students in using AI-powered learning resources effectively. Without proper training, the full potential of AI in Biology education may remain untapped.

Financial Constraints

The cost of acquiring, implementing, and maintaining AI-powered educational tools presents a significant challenge. Schools in Gumel Local Government Area, like many others in Nigeria, operate under tight budgets and struggle to afford high-tech learning solutions. AI software, digital platforms, and hardware such as smartboards, computers, and VR headsets require substantial financial investment. Government funding, private sector support, and strategic

collaborations with EdTech companies could help overcome this barrier.

Ethical Concerns

AI in education raises ethical issues, including student data privacy, algorithmic bias, and concerns about over-reliance on technology. AI systems collect and analyze large amounts of student data, raising questions about data security and unauthorized access. Additionally, biased AI algorithms may reinforce inequalities in education. Schools must establish clear ethical guidelines, data protection policies, and transparent AI governance frameworks to address these concerns. (Selwyn, 2019)

Resistance to Technological Change

Despite the potential benefits of AI, some educators, parents, and policymakers remain skeptical about its effectiveness in education. Fear of job displacement, distrust in AI's decision-making processes, and reluctance to shift from traditional teaching methods contribute to resistance against AI adoption. Creating awareness, providing evidence-based demonstrations of AI's effectiveness, and fostering an AI-friendly educational culture can help overcome this resistance.

Policy Recommendations (Federal Ministry of Education Nigeria, 2021)

Government Investment in AI Infrastructure

One of the major barriers to AI integration in Nigerian schools, including those in Gumel Local Government Area, is inadequate infrastructure. Many schools lack reliable internet connectivity, stable power supply, and the necessary hardware to implement AI-driven learning tools. The government must prioritize investment in digital infrastructure, such as high-speed internet, smart classrooms, and cloud-based educational platforms. Providing AI-powered devices to schools will help bridge the digital divide and create an environment where students can benefit from AI-enhanced learning experiences.

Teacher Training and Capacity Building

For AI to be successfully integrated into Biology education, teachers must be adequately trained to use AI-driven tools effectively. Many educators lack the necessary digital literacy skills to incorporate AI into their teaching methodologies. Governments and educational institutions should implement nationwide training programs to equip teachers with AI competencies, including how to use AI-powered tutoring systems, virtual labs, and automated assessment tools. Regular workshops and professional development programs should be organized to ensure

that teachers stay up-to-date with emerging AI technologies in education.

Industry-Academic Partnerships

Collaboration between the education sector, technology firms, and policymakers is crucial for developing and implementing AI-driven educational solutions. Private sector partnerships can facilitate the development of AI-based Biology learning resources, provide funding for research on AI in education, and support the deployment of AI-driven learning management systems in schools. Universities and research institutions should work closely with EdTech companies to create AI tools tailored to the Nigerian educational context, ensuring their accessibility and effectiveness in Biology instruction.

Ethical Guidelines for AI Implementation

AI implementation in education raises several ethical concerns, including data privacy, algorithmic bias, and the potential over-reliance on AI-driven instruction. To address these issues, policymakers must develop comprehensive ethical guidelines that regulate AI use in schools. These guidelines should outline clear data protection policies to ensure that student information remains confidential. Additionally, AI algorithms should be designed to be transparent and fair, preventing bias in personalized learning systems. Schools should also strike a balance between AI-assisted teaching and traditional teacher-led instruction to preserve the human element in education.

Awareness Campaigns and Public Sensitization

Many stakeholders in the education sector, including parents, educators, and policymakers, remain skeptical about the effectiveness of AI in education. Awareness campaigns should be conducted to educate stakeholders about the benefits of AI in Biology instruction and dispel common misconceptions. Public sensitization programs can highlight success stories from other countries and pilot AI-integration projects in Nigeria, showcasing the potential of AI to improve learning outcomes. Engaging educational stakeholders in discussions about AI adoption can help build confidence in its implementation and foster a more receptive attitude toward technological advancements in education.

By implementing these policy recommendations, Nigeria can create an enabling environment for AI-driven Biology education. Investing in infrastructure, training educators, fostering collaborations, addressing ethical concerns, and promoting awareness will contribute to the successful integration of AI into secondary school Biology instruction, ultimately

improving learning experiences and educational outcomes.

Future Prospects of AI in Biology Education (World Economic Forum, 2020)

AI has the potential to revolutionize Biology education by addressing educational inequalities and fostering a more interactive and dynamic learning experience. In underserved regions such as Gumel Local Government Area, AI can provide students with access to virtual Biology labs, AI-driven tutors, and real-time feedback mechanisms, thereby compensating for the lack of physical resources. These innovations can help bridge the digital divide and provide equal learning opportunities for all students, regardless of geographical location.

Future research on AI's long-term impact on critical thinking, creativity, and problem-solving in Biology education is essential. AI has the ability to encourage students to develop analytical skills by presenting them with complex biological problems and guiding them through the process of scientific inquiry. Understanding how AI enhances cognitive development in students will be crucial in determining its overall effectiveness in Biology education.

The role of AI in science education in Nigeria will continue to evolve, with broader implications for national development. As AI technologies advance, they will become more accessible and affordable, allowing for widespread adoption in Nigerian schools. AI-driven education can contribute to producing a workforce equipped with digital skills, fostering scientific research, and enhancing innovation in Nigeria. To fully harness these future prospects, strategic investments, policy development, and continuous research on AI's impact on education are necessary.

Recommendations

These recommendations focus on research design, implementation, policy, and community engagement:

1. Conduct a Baseline Needs Assessment

Objective: Understand the current state of biology education and technological readiness. Survey stakeholders (teachers, students, principals) to assess: availability of digital infrastructure (computers, internet access), teachers' digital literacy and openness to AI tools, students' exposure to or interest in digital learning, analyze WAEC/NECO biology results over the past 3 to 5 years to establish academic performance trends.

2. Design Pilot AI-Integrated Biology Programs

Objective: Implement small-scale AI solutions to evaluate effectiveness.

Introduce AI-based tools such as: Intelligent tutoring systems (e.g., Century Tech, Squirrel AI) for individualized learning, Voice assistants and chatbots for answering biology-related questions, Visual recognition tools (e.g., AI microscopes, Google Lens) to assist in learning about anatomy, plant species, and microorganisms. Also, the use of interactive platforms such as: Khan Academy with AI tutors (Khanmigo) for supporting human biology topics, Edmodo, Quizizz, or ChatGPT-based solutions for test prep and instant feedback.

3. Train Biology Teachers on AI Tools

Objective: Build teacher capacity to integrate AI into lessons.

Organize workshops in collaboration with Jigawa State Ministry of Education, NGOs or tech companies (e.g., Teach For Nigeria, Mind the Gap). Federal College of Education (Technical) Bichi or Bayero University, Kano.

Training areas should include: the Basics of AI and educational technology, how to integrate AI into the biology curriculum (e.g., cell biology, ecology, genetics) and use of data dashboards to monitor student progress.

4. Establish Research Framework to Monitor Impact

Objective: Measure the impact of AI integration on biology learning outcomes.

Use a quasi-experimental design: to create experimental and control groups of schools, measure academic performance, engagement and interest in biology before and after AI tool usage. Collect qualitative data via focus group discussions with students and teachers, classroom observations, teacher reflective journals. Also, use analysis tools like SPSS or NVivo for mixed-methods evaluation.

5. Improve Digital Infrastructure in Pilot Schools

Objective: Provide enabling environment for effective AI integration.

Recommend government and private sector support to supply solar-powered devices (due to frequent power outages), provide affordable internet access in schools (e.g., through EduNet by NITDA) and also advocate for inclusion of digital biology content in local curriculum plans.

6. Foster Community and Policy Engagement

Objective: Ensure local support and policy alignment.

Host town hall meetings with parents, local chiefs, and religious leaders to promote the benefits of AI in education.

Encourage Jigawa State Universal Basic Education Board (SUBEB) to incorporate AI strategies in educational policy. Include AI literacy and ethics in the biology curriculum as a pilot topic.

7. Promote Inclusive Access to AI Tools

Objective: Ensure equity in AI integration.

Prioritize girls' schools and rural schools in AI interventions to close the gender and digital divide and provide multilingual AI tools or translation support for Hausa-speaking students to ensure understanding.

8. Partner with Institutions and Tech Startups

Objective: Sustain and scale AI innovations.

Collaborate with National Information Technology Development Agency (NITDA), NGOs like eLIMU, Onebillion, or Andela for curriculum support. Local teacher colleges for continuous professional development.

9. Document and Disseminate Best Practices

Objective: Share knowledge and inform scale-up.

Publish findings in academic journals and present at education technology conferences in Nigeria and encourage Ministry of Education to replicate successful models in other LGAs.

10. Develop Localized AI Content

Objective: Ensure relevance to local syllabus and context.

Create AI-assisted resources aligned with Nigerian Secondary School Biology Curriculum (NERDC) and develop gamified and culturally relevant biology modules using AI storytelling and simulations.

Conclusion

The integration of AI into Biology education presents a transformative opportunity to enhance learning outcomes, improve accessibility, and promote scientific inquiry among students. AI-powered learning tools, such as virtual labs, intelligent tutoring systems, and automated assessments, can help bridge the gaps in traditional teaching methods by offering personalized and engaging learning experiences.

However, the successful implementation of AI in Nigerian secondary schools requires addressing key challenges such as inadequate digital infrastructure, teacher preparedness, financial constraints, and ethical concerns. The lack of reliable internet connectivity, access to AI-enabled devices, and teacher training remains significant hurdles that need to be tackled through targeted investments and strategic policy

interventions. Governments, educational institutions, and private sector stakeholders must work collaboratively to ensure AI technologies are accessible and effectively integrated into the curriculum.

Additionally, ethical considerations surrounding AI implementation must be carefully managed. Issues such as student data privacy, algorithmic fairness, and the potential over-reliance on AI for learning require the establishment of clear regulatory frameworks and best practices. Schools should aim to strike a balance between AI-assisted learning and traditional teacher-led instruction, ensuring that the human element remains integral to the educational experience.

Looking forward, the future of AI in Biology education is promising. As AI technology continues to evolve, it will become more sophisticated, accessible, and affordable, providing new opportunities to revolutionize science education. AI has the potential to bridge educational gaps in underserved regions by offering remote and personalized learning solutions, ultimately contributing to national development and scientific progress. To fully harness these benefits, it is crucial that policymakers, educators, and researchers continue to explore innovative ways to integrate AI into the education system while addressing the challenges that come with it.

By embracing AI-driven educational reforms, Nigeria can create a more inclusive, technologically advanced, and forward-thinking learning environment that prepares students for the demands of the modern scientific and technological world. The journey toward AI-powered Biology education requires commitment, collaboration, and sustained investment, but the potential rewards in terms of improved learning outcomes, student engagement, and educational equity make it a goal worth pursuing.

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