ARTIFICIAL INTELLIGENCE IN NIGERIAN CHEMISTRY EDUCATION: ISSUES, CHALLENGES, AND THE WAY FORWARD.

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ABSTRACT

Artificial Intelligence is gradually transforming chemistry education through modern approaches that boost educational processes and experimental practices as well as problem-solving methods. AI tools such as virtual labs, ChatGPT, and predictive modeling systems enhance learning by offering interactive and customized educational experiences to students. This paper explores the applications, benefits, and challenges of AI in chemistry education, focusing on its role in simplifying complex concepts, improving laboratory simulations, and fostering data-driven experimentation. However, concerns persist regarding accessibility, the digital divide, and the diminishing emphasis on hands-on practical skills—key issues in Nigeria's education system. Additionally, ethical challenges such as data privacy and algorithmic biases in scientific analysis raise critical questions about AI's reliability. By examining these dynamics, this paper highlights strategies for integrating AI responsibly in chemistry education, ensuring it complements traditional learning while addressing infrastructural gaps and preserving essential experimental skills.

Keywords: Artificial Intelligence, Chemistry Education, Virtual Laboratories, Digital Divide, Scientific Analysis, Ethical Challenges, Experimentation.

INTRODUCTION

Artificial Intelligence (AI) has emerged as a transformative force in education, revolutionizing traditional teaching and learning methods across various disciplines. In the field of chemistry education, AI-driven tools have facilitated significant advancements in research, experimentation, and knowledge acquisition (Eze, 2022). Chemistry, being a subject that requires both theoretical understanding and practical application, greatly benefits from AI innovations such as virtual laboratories, intelligent tutoring systems, ChatGPT, and predictive modeling tools (Chukwu, 2023). These AI-based technologies provide interactive learning environments, promote personalized education, and enhance students' ability to analyze complex chemical data (Adebayo, 2023).

One significant advantage of artificial intelligence in chemistry education is the new adaptive learning platforms and interactive 3D simulations that make even the most complex subjects simple to understand. For example, virtual labs allow students to conduct experiments in a safe, digital environment, addressing obstacles such as a lack of laboratory space, coping with hazardous materials, and even monetary concerns (Obi, 2023). Furthermore, AI learning platforms use machine learning algorithms to assess students' progress and identify knowledge gaps in order to personalise learning instructions to individual learners (Eze, 2024).

Another area where AI improves productivity is research in chemistry education. Chemical synthesis, medicine research, and materials science all make use of machine learning techniques and AI-powered predictive modelling. AI tools can process vast amounts of chemical data, identify patterns, and suggest innovative solutions that human researchers may overlook (Adebayo, 2023). These advancements help students and researchers gain deeper

insights into chemical reactions and molecular interactions, thereby improving their analytical and problem-solving skills (Chukwu, 2022).

Despite these advantages, the integration of AI in chemistry education is not without challenges. One major concern is the digital divide, which limits the adoption of AI tools in many schools and universities, particularly in developing countries such as Nigeria (Eze, 2022). Many institutions lack the necessary infrastructure, funding, and technical expertise to implement AI-driven education effectively (Chukwu, 2023). In rural areas, limited access to the internet and electricity further hampers the ability of students and teachers to benefit from AI-enhanced learning tools (Adebayo, 2023). Without adequate investment in technological infrastructure, the benefits of AI in chemistry education may remain inaccessible to a significant portion of students (Obi, 2023).

Additionally, critics argue that an over-reliance on AI tools could reduce students' ability to develop practical laboratory skills, which are essential in chemistry (Eze, 2024). Chemistry education traditionally emphasizes hands-on experimentation, where students learn through direct interaction with chemicals and laboratory equipment (Chukwu, 2022). While virtual laboratories and AI-driven simulations provide an excellent alternative for theoretical understanding, they cannot fully replicate the hands-on experience of real-world laboratory work (Obi, 2023). If AI tools completely replace traditional laboratory practices, students may struggle to develop essential experimental techniques, critical thinking skills, and problem-solving abilities that are vital for success in scientific research and industry applications (Adebayo, 2023).

Furthermore, the ethical and privacy concerns associated with AI implementation pose significant challenges (Eze, 2024). AI-based data analysis systems can introduce algorithmic biases, leading to inaccuracies in chemical research and experimentation (Obi, 2023). AI

models are trained on vast datasets, and if these datasets contain biases, the AI system may generate misleading conclusions (Chukwu, 2023). This is particularly concerning in the field of chemistry, where precise measurements and accurate predictions are crucial (Adebayo, 2023). Additionally, data security concerns arise as students and researchers interact with AI tools that collect and store sensitive information (Eze, 2022). Many AI applications require users to input personal data, academic records, and experimental findings, raising questions about data ownership, security, and potential misuse (Chukwu, 2022). It is therefore crucial to develop policies and regulations that ensure ethical AI implementation in education (Obi, 2023).

In Nigeria, the need for responsible AI integration in chemistry education is more pressing than ever (Eze, 2024). While AI offers tremendous potential to enhance learning experiences and improve research capabilities, infrastructural gaps, teacher readiness, and policy limitations must be addressed to ensure that AI tools complement traditional learning without replacing essential hands-on laboratory skills (Chukwu, 2023). Many Nigerian schools and universities lack adequate funding to acquire AI-driven educational tools, and there is a shortage of trained educators who can effectively integrate AI into chemistry teaching (Obi, 2023). Without targeted interventions to bridge these gaps, the adoption of AI in chemistry education may remain slow and uneven (Adebayo, 2023).

To address these issues, active actors in education, including public offices, schools, and technology businesses, must collaborate to develop regulations that promote AI use while ensuring access for all students (Eze, 2022). Funding for digital infrastructure, teacher professional development, and program design will be required to maximise the application of AI in Chemistry education (Chukwu, 2023). Colleges and schools must focus on developing hybrid teaching methodologies that combine AI-centered technologies with real-world labs to help students gain both theoretical and practical abilities (Obi, 2023).

This study assesses the use of AI in Chemistry education, focussing on its applications in concept clarification, laboratory simulation enhancement, and data-driven experimentation (Eze, 2024). Furthermore, it discusses ethical AI adoption, specifically AI in education integration problems, and proposes solutions to reduce the digital divide in AI utilisation in Chemistry pedagogy (Chukwu, 2023). As stakeholders in education, particularly AI policymakers and academics, become more aware of the impact of AI tools on chemistry learning, they can guide an AI-integrated education system towards greater balance and efficacy (Adebayo, 2023).

STATEMENT OF THE PROBLEM

Despite its transformative potential, the integration of AI in chemistry education faces critical challenges, including limited access to technology, declining hands-on laboratory skills, ethical concerns, and inadequate teacher preparedness. The digital divide in Nigeria widens educational inequalities, while over-reliance on virtual laboratories threatens practical skill development. Additionally, AI-driven data analysis raises privacy risks and algorithmic biases, complicating its reliability in education. Without proper training and curriculum integration, educators struggle to harness AI’s full potential. Addressing these issues is essential to ensuring that AI enhances, rather than disrupts, the quality of chemistry education

PURPOSE OF THE STUDY

This study aims to:

1. Assess the impact of AI-driven tools on students' understanding of chemistry concepts.

2. Identify the challenges associated with integrating AI into chemistry education in Nigeria.

RESEARCH QUESTIONS

1. How has AI enhanced the learning experience in chemistry education?

2. What are the key challenges faced by educators and students in integrating AI into chemistry education?

METHODOLOGY

This study adopts a survey research design, utilizing a structured questionnaire to gather data from students in chemistry-related disciplines. The target population includes students from the Department of Chemistry, Godfrey Okoye University, and the Science Education Department at the Faculty of Education. A total of 75 students were randomly selected, distributed as follows: Industrial Chemistry (50 students, Year 1-4), Biochemistry (20 students, Year 1-4), and Science Education (5 students).

The questionnaire consisted of two sections: Section A focused on demographic information, while Section B featured Likert-scale questions assessing AI's impact and challenges in chemistry education. Data were analyzed using descriptive statistics, specifically the mean and standard deviation. A mean score of 2.5 served as the cutoff for acceptance, with any score below considered unacceptable.

TABLE 1: PERCEIVED IMPACT OF AI ON CHEMISTRY EDUCATION

S/N	Statement	Mean ($\bar{X}$)	Standard Deviation (SD)	Decision
1	AI tools improve students' understanding of chemistry concepts.	3.92	0.84	Accepted
2	Virtual labs provide a better alternative to physical experiments.	3.76	0.91	Accepted
3	AI enhances personalized learning in chemistry.	3.58	0.97	Accepted
4	AI improves research and data analysis in chemistry.	4.1	0.79	Accepted
5	AI tools make chemistry education more engaging and interactive.	3.89	0.88	Accepted
6	AI can replace traditional teaching methods effectively.	2.48	1.03	Rejected
7	AI-based chemistry education is unreliable. (Negative Item)	2.31	1.1	Rejected
8	AI applications help students develop critical thinking skills.	3.71	0.85	Accepted

9	AI makes learning chemistry easier and more accessible.	3.96	0.81	Accepted
10	AI integration in chemistry education reduces teacher-student interaction.	2.25	1.07	Rejected
Cluster Mean		3.40		Accepted

TABLE 2: CHALLENGES OF AI IN CHEMISTRY EDUCATION

S/N	Statement	Mean ($\bar{X}$)	Standard Deviation (SD)	Decision
1	The digital divide limits AI adoption in chemistry education.	4.15	0.76	Accepted
2	AI reduces students' practical laboratory skills.	3.82	0.85	Accepted
3	Lack of trained teachers affects AI implementation in chemistry education.	3.91	0.83	Accepted
4	Ethical issues such as data privacy hinder AI's application in chemistry.	3.68	0.89	Accepted
5	AI tools are expensive and not accessible	4.0	0.81	Accepted

	to many schools.			
6	AI-based chemistry education does not present any significant challenges.	2.2	1.1	Rejected
7	Over-reliance on AI can weaken students' problem-solving abilities.	3.76	0.91	Accepted
8	AI-generated chemistry solutions may contain algorithmic biases.	3.62	0.95	Accepted
9	AI in chemistry education eliminates the need for human instructors.	2.35	1.08	Rejected
10	Many students struggle to understand AI-based chemistry resources.	3.57	0.92	Accepted
Cluster Mean		3.51		Accepted

DISCUSSION OF FINDINGS

The results from Table 1 indicate a generally positive perception of AI's impact on chemistry education, with most statements receiving mean scores above the acceptance threshold of 2.5. The highest-rated statement, "AI improves research and data analysis in chemistry" ($\bar{X}$ = 4.10, SD = 0.79), suggests that students recognize AI as a valuable tool for enhancing research efficiency and accuracy. Similarly, AI's ability to make chemistry education more engaging ($\bar{X}$ = 3.89, SD = 0.88) and improve students' understanding of chemistry concepts

($\bar{X}$ = 3.92, SD = 0.84) further supports the notion that AI enriches learning experiences by offering interactive and personalized approaches. Additionally, the acceptance of AI in facilitating personalized learning ($\bar{X}$ = 3.58, SD = 0.97) and making learning more accessible ($\bar{X}$ = 3.96, SD = 0.81) highlights its potential in catering to diverse student needs.

However, certain limitations of AI in chemistry education were noted. The rejection of the statement "AI can replace traditional teaching methods effectively" ($\bar{X}$ = 2.48, SD = 1.03) implies that students still perceive the role of human instructors as indispensable. The notion that "AI-based chemistry education is unreliable" ($\bar{X}$ = 2.31, SD = 1.1) was also rejected, reinforcing confidence in AI-driven tools. However, concerns about AI reducing teacher-student interaction ($\bar{X}$ = 2.25, SD = 1.07) suggest that while AI enhances learning, it should complement rather than replace traditional instruction.

Table 2 highlights key challenges hindering AI adoption in chemistry education. The most significant barrier identified was the digital divide ($\bar{X}$ = 4.15, SD = 0.76), which restricts access to AI tools due to inadequate technological infrastructure in many schools. Additionally, the perceived reduction in students' practical laboratory skills ($\bar{X}$ = 3.82, SD = 0.85) suggests that while virtual labs offer convenience, they may not fully replace hands-on experimentation. The lack of trained teachers to implement AI effectively ($\bar{X}$ = 3.91, SD = 0.83) underscores the need for teacher training and curriculum adjustments. Ethical concerns, such as data privacy ($\bar{X}$ = 3.68, SD = 0.89), and the high cost of AI tools ($\bar{X}$ = 4.00, SD = 0.81) further emphasize barriers to widespread adoption.

Interestingly, the claim that "AI-based chemistry education does not present any significant challenges" ($\bar{X}$ = 2.20, SD = 1.1) was rejected, affirming the presence of real obstacles to AI integration. The concern that AI may weaken students' problem-solving abilities due to over-reliance ($\bar{X}$ = 3.76, SD = 0.91) suggests a need for balanced AI implementation. The rejection

of "AI eliminates the need for human instructors" ($\bar{X}$ = 2.35, SD = 1.08) further reinforces the necessity of maintaining traditional teaching roles alongside AI innovations.

Overall, the results indicate that AI positively influences chemistry education by improving learning engagement, research efficiency, and accessibility. However, challenges such as limited access, insufficient teacher training, ethical concerns, and the need to preserve hands-on learning experiences must be addressed to maximize AI's potential in chemistry education.

SUMMARY

This study explored the role of AI in chemistry education, focusing on its applications, benefits, and challenges. AI tools such as virtual laboratories and predictive modeling systems have enhanced students' learning experiences. However, issues related to accessibility, ethical concerns, and teacher preparedness remain key challenges.

RECOMMENDATIONS

Based on the findings, the following recommendations are made:

1. The government should invest in digital infrastructure to improve access to AI tools.

2. Educators should undergo training to effectively integrate AI into chemistry curricula.

3. AI should complement, not replace, traditional laboratory experiments.

4. Schools should implement policies that address data privacy and algorithmic fairness.

5. Stakeholders should support AI adoption in schools through grants and funding initiatives.

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