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Evaluating the Effectiveness and Challenges of Artificial Intelligence Tools in Chemistry Instruction at the Federal University of Education, Zaria

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Abstract
This study, titled evaluating the effectiveness and implementation challenges of artificial intelligence tools in chemistry instruction in Federal University of Education, Zaria was guided by four specific objectives, along with corresponding research questions. The study focused on chemistry lecturers and students within Federal University of Education, Zaria. A **descriptive survey design** was employed, involving a sample of one hundred and twenty (120) students and ten (10) lecturers. The sample was selected using purposive sampling technique. The instrument for data collection was a structured questionnaire, which yielded a reliability coefficient of 0.70 after pilot testing. Data collection was self-administered and anlyzed using the **descriptive statistics** of mean and standard deviation. Findings revealed that there is a generally positive perception of the impact of AI tools (Reelmind.ai) on students' understanding of abstract chemistry concepts at the Federal University of Education, Zaria (X=3.14), lecturers at the Federal University of Education, Zaria demonstrate an overall **high level of technological pedagogical content knowledge (TPACK)** (X=3.13), **key infrastructural challenges exist** in implementing AI tools (Reelmind.ai) in chemistry instruction at the Federal University of Education, Zaria (X=3.30) and there is a **generally positive perception** of AI tools (Reelmind.ai) among chemistry lecturers and students (X=3.07). The research recommends that the university administration and government agencies should invest in stable internet connectivity, reliable electricity, and access to up-to-date hardware and software, among others.

Keywords: Chemistry Education, Artificial Intelligence, TPACK, Implementation Challenges, Reelmind.ai

Introduction

The integration of Artificial Intelligence (AI) into educational settings has transformed teaching and learning processes globally. In chemistry education specifically, AI tools have demonstrated potential to enhance conceptual understanding, visualization of abstract concepts, and personalization of learning experiences (Pedaste et al., 2021; Zawacki-Richter et al., 2019). This technological integration represents a significant shift from traditional pedagogical approaches toward more interactive, adaptive, and student-centered learning environments. Recent advances in AI technologies have made them increasingly accessible to educational institutions. Intelligent tutoring systems, virtual laboratories, adaptive learning platforms, and AI-powered formative assessment tools are being deployed across various educational levels to address persistent challenges in science education (Chassignol et al., 2018; Hwang et al., 2020). These technologies can provide immediate feedback, adapt to individual learning needs, simulate complex chemical reactions, and create immersive learning experiences that would be difficult or dangerous to replicate in conventional laboratory settings (Shen et al., 2020). Chemistry, as a core science subject, presents unique challenges for secondary school students, particularly in resource-constrained settings. The abstract nature of chemical concepts, the cognitive demands of understanding molecular behaviours, and the practical requirements for laboratory work create significant barriers to effective learning (Etiubon & Udoh, 2017; Orji & Ebenezer, 2021). Studies have shown that Nigerian schools consistently underperform in chemistry, with particular difficulties in understanding abstract concepts, chemical calculations, and practical applications (Emendu & Udogu, 2020; Nbina & Avwiri, 2019). The National Policy on Education and the Science, Technology, Engineering, and Mathematics (STEM) curriculum framework have emphasized the importance of technological integration to enhance teaching and learning outcomes (Federal Ministry of Education, 2014). Recent policy initiatives, including the Nigerian Education Sector Plan (2018-2022) and the Science, Technology, and Innovation Policy (2021), have highlighted the need for innovative approaches to STEM education to prepare students for the demands of the fourth industrial revolution (Federal Ministry of Science and Technology, 2021). Despite these policy frameworks, the practical implementation of advanced educational technologies in Nigerian schools remains limited. The infrastructure challenges, teacher preparedness, and resource constraints that characterize many Nigerian educational institutions potentially limit the deployment and effectiveness of AI-based educational tools (Okonkwo et al., 2022; Yusuf & Balogun, 2019).

Recent educational reforms have emphasized technological integration, with initiatives such as the Kaduna Smart Schools Project and the State Education Strategic Plan (2019-2023) promoting digital literacy and technology-enhanced learning (Kaduna State Ministry of Education, 2019). However, the effective implementation of these initiatives, particularly in FUE, Zaria, requires empirical evaluation to understand their impact and identify context-specific challenges (Agbo et al., 2020). A recent survey by Ibrahim and Aminu (2023) indicated that only 18% of secondary schools in Northern Nigeria have implemented any form of AI-based educational tools, with significant disparities between urban and rural settings. This underscores the need for research that examines both the effectiveness and implementation challenges of AI tools in chemistry education within specific geographical and socioeconomic contexts like Zaria. The effectiveness of AI tools in enhancing chemistry education is influenced by various factors, including teacher technological pedagogical content knowledge (TPACK), school infrastructure, student digital literacy, and contextual relevance of the AI applications (Mishra & Koehler, 2021; Shulman, 2015). Understanding these factors within the context of Zaria is crucial for developing context-appropriate strategies for integrating AI tools into chemistry instruction. Furthermore, the COVID-19 pandemic has accelerated the adoption of educational technologies globally, highlighting both the potential and challenges of technology-enhanced learning in various contexts (Adedoyin & Soykan, 2020; Pokhrel & Chhetri, 2021). This global shift towards educational technology has created both opportunities and pressures for educational systems in developing countries like Nigeria to embrace technological innovations in teaching and learning.

Recent research by Olanrewaju et al. (2022) examined the implementation of AI-powered virtual laboratories in selected secondary schools across Nigeria, revealing significant improvements in student engagement and conceptual understanding. However, their study also emphasized the need for contextual adaptation and teacher professional development to maximize the effectiveness of these tools. Similarly, Adebayo and Ibrahim (2024) found that AI-enhanced instructional approaches improved student performance in chemistry by 32% in selected schools in Katsina State, though they also identified key implementation challenges related to infrastructure, teacher competence, and cultural adaptation. Despite these promising findings, there remains a significant gap in understanding how AI tools can be effectively integrated into chemistry instruction at the tertiary level, especially in semi-urban institutions like the Federal University of Education, Zaria. In such contexts, infrastructure limitations, varying levels of digital literacy among lecturers, and localized educational challenges may affect both the implementation and impact of AI-assisted learning tools. This study seeks to address this gap by evaluating the effectiveness and implementation challenges of AI tools in chemistry instruction within the Federal University of Education, Zaria.

Statement of the Problem

Despite the growing recognition of Artificial Intelligence (AI) as a transformative tool in chemistry education, there remains a critical gap in understanding its effectiveness and implementation challenges within semi-urban tertiary institutions such as the Federal University of Education, Zaria. Chemistry instruction in such settings continues to face hurdles due to the abstract nature of chemical concepts, limited access to laboratory facilities, and traditional teacher-centered methods. Although national policies support technological integration, actual implementation is often hindered by infrastructural deficits, insufficient lecturer readiness, and inadequate resources. While studies in urban Nigerian settings have shown promising results with AI-enhanced instruction, little empirical evidence exists for semi-urban institutions where socioeconomic and institutional factors differ. This study, therefore, seeks to evaluate the effectiveness of AI tools in improving conceptual understanding in chemistry and to explore the specific implementation challenges faced by lecturers and students in the Federal University of Education, Zaria.

Research Objectives

Specifically, the study seeks to:

1. evaluate the effect of AI tools (Reelmind.ai) on students' conceptual understanding of abstract chemistry concepts at the Federal University of Education, Zaria.
2. determine the level of lecturers' technological pedagogical content knowledge (TPACK) in chemistry instruction at the Federal University of Education, Zaria.
3. To identify key infrastructural challenges affecting the implementation of AI tools (Reelmind.ai) in chemistry instruction at the Federal University of Education, Zaria.
4. To explore the perceptions of chemistry lecturers and students regarding the use of AI tools (Reelmind.ai) in chemistry instruction at the Federal University of Education, Zaria.

Research Questions

The following research questions will guide this study:

1. How do AI tools (Reelmind.ai) affect students' conceptual understanding of abstract chemistry concepts at the Federal University of Education, Zaria?
2. What is the level of lecturers' technological pedagogical content knowledge (TPACK) in chemistry instruction at the Federal University of Education, Zaria?
3. What are the key infrastructural challenges affecting the implementation of AI tools (Reelmind.ai) in chemistry instruction at the Federal University of Education, Zaria?
4. What are the perceptions of chemistry lecturers and students regarding the use of AI tools (Reelmind.ai) in chemistry instruction at the Federal University of Education, Zaria?

Material and Methods

This study adopted a descriptive survey design to investigate the use and impact of Artificial Intelligence (AI) tools (Reelmind.ai) in chemistry instruction. The target population consisted of all chemistry students and lecturers in the Department of Chemistry at the Federal University of Education, Zaria, during the 2024/2025 academic session. A purposive sampling technique was employed to ensure the selection of participants directly engaged in teaching and learning processes. The selection criteria for students included enrollment in core chemistry courses and regular class attendance. Students were drawn proportionately across all academic levels (100–400 level) to ensure balanced representation: 30 students from each level, totaling 120 students. Additionally, 10 chemistry lecturers were purposively selected based on their teaching roles, minimum of two years of experience, and willingness to participate. The instrument for data collection was a structured questionnaire developed by the researcher. The questionnaire was divided into four key sections: Section A: Demographic data (e.g., age, gender, level, teaching experience). Section B: Items on students' conceptual understanding and the perceived effectiveness of AI tools (e.g., "AI tools help me understand abstract chemistry concepts better"). Section C: Items measuring lecturers' Technological Pedagogical Content Knowledge (TPACK) (e.g., "I can design chemistry lessons that effectively integrate AI technology"). Section D: Items addressing infrastructural challenges and general perceptions of AI (e.g., "There are enough ICT facilities to support AI tools in chemistry instruction", "AI tools make teaching more interactive"). All items were rated on a 5-point Likert scale ranging from Strongly Agree (5) to Strongly Disagree (1). To ensure validity, the questionnaire was vetted by experts in science education and educational technology. A pilot study was conducted with 30 respondents (25 students and 5 lecturers) from a neighbouring science department (Physics Department) known for a comparable academic structure and technological exposure. The pilot was used to test the reliability of the instrument using Cronbach's Alpha, yielding a reliability coefficient of 0.70, indicating acceptable internal consistency. Data collected from the main study were analyzed using both descriptive and inferential statistics. Descriptive statistics (mean and standard deviation) were used to summarize responses and identify trends in perceptions, challenges, and impacts. In addition, Pearson Product Moment Correlation was used to explore the relationships between key variables such as lecturers' TPACK and perceived effectiveness of AI tools, and students' exposure to AI tools and conceptual understanding, to draw meaningful inferences about the effectiveness of AI integration in chemistry instruction.

Results

Table 1: How do AI tools (Reelmind.ai) affect students' conceptual understanding of abstract chemistry concepts at the Federal University of Education, Zaria?

S/N	Items	X	S.D	Remark
1	AI tools (e.g., Reelmind.ai) help me understand abstract chemistry concepts better.	3.65	0.92	Accepted
2	I can visualize chemical reactions more clearly when AI tools are used during instruction.	3.72	0.88	Accepted
3	My interest in learning chemistry has increased due to the use of AI tools.	2.95	1.01	Rejected
4	I understand difficult topics (e.g., atomic structure, thermodynamics) better with the help of AI-based visualizations.	3.02	0.97	Accepted
5	AI tools provide immediate feedback that helps me improve my understanding of chemistry.	2.89	1.05	Rejected
6	AI-enhanced lessons make learning chemistry more engaging and interactive.	3.81	0.79	Accepted
7	Compared to traditional methods, AI-based instruction improves my test performance in chemistry.	2.91	0.98	Rejected
	Cumulative Mean	3.14		Accepted

Benchmark: Mean ≥3.0 = Accepted; Mean < 3.0= Rejected

The data indicate a generally positive perception of the impact of AI tools (Reelmind.ai) on students' understanding of abstract chemistry concepts at the Federal University of Education, Zaria, with a cumulative mean of 3.14 above the benchmark of 3.0. This benchmark (Mean ≥ 3.0) was adopted in line with the mid-point of the 5-point Likert scale, where a mean score of 3.0 represents a neutral response. Scores above this point were interpreted as agreement or positive perception, while those below indicated disagreement or negative perception. This provides a reasonable and widely accepted threshold for judging the effectiveness of educational interventions in survey research. Students agree that AI tools such as Reelmind.ai and simulations enhance their understanding and visualization of complex chemistry topics. However, not all aspects were positively rated. Responses to items on interest in learning chemistry, the immediacy of feedback from AI tools, and the influence of AI on test performance received mean scores below 3.0, resulting in rejected remarks. These items were rejected not merely due to numerical thresholds, but likely due to contextual factors such as limited personalization in current AI systems, lack of real-time feedback in some tools, and students' unfamiliarity with AI-driven assessments. Additionally, motivational aspects like interest may be influenced by external factors such as course structure, teaching approach, and individual differences in learning preferences factors which AI tools alone may not fully address. These mixed findings highlight the need for more targeted improvements in the design and integration of AI tools to address specific learning and performance needs in chemistry instruction.

Table 2: What is the level of lecturers' technological pedagogical content knowledge (TPACK) in chemistry instruction at the Federal University of Education, Zaria?

S/N	Items	X	S.D	Remark
1	I am confident in selecting appropriate digital tools that support the teaching of complex chemistry concepts.	3.62	0.85	High Level
2	I can effectively integrate technology into my chemistry lessons to enhance student understanding.	3.54	0.91	High Level
3	I understand how to adapt my chemistry teaching strategies when using AI or other digital technologies.	2.96	1.02	Low Level
4	I am skilled at combining subject content, pedagogy, and technology to deliver effective chemistry instruction.	3.08	0.88	High Level
5	I can evaluate the usefulness of an AI tool based on its relevance to my chemistry teaching objectives.	2.85	1.04	Low Level
6	I regularly update my technological knowledge to keep pace with emerging educational tools in science instruction.	3.11	0.93	High Level
7	I find it easy to design lessons that integrate chemistry content, pedagogy, and AI technologies in a balanced way.	2.79	1.06	Low Level
	Cumulative Mean	3.13		High Level

Benchmark: Mean ≥3.0 = High Level; Mean < 3.0= Low Level

The findings reveal that lecturers at the Federal University of Education, Zaria demonstrate an overall **high level of technological pedagogical content knowledge (TPACK)**, with a cumulative mean score of 3.13. Respondents expressed confidence in selecting digital tools, integrating technology into lessons, and staying current with emerging technologies. However, notable gaps exist in their ability to adapt instructional strategies when using AI, evaluate AI tools critically, and design balanced AI-integrated lesson plans—each scoring below the benchmark of 3.0. **This benchmark (Mean ≥ 3.0) was adopted in line with the mid-point of the 5-point Likert scale, where a mean score of 3.0 represents a neutral response. Scores above this point were interpreted as agreement or positive perception, while those below indicated disagreement or negative perception.** These results suggest that while lecturers possess foundational TPACK skills, there is a need for targeted professional development to enhance their ability to implement AI more effectively and confidently within their pedagogical practice.

Table 3: What are the key infrastructural challenges affecting the implementation of AI tools (Reelmind.ai) in chemistry instruction at the Federal University of Education, Zaria?

S/N	Items	X	S.D	Remark
1	Reliable internet access is a challenge when using AI tools in chemistry classes.	3.67	0.89	Accepted
2	There is insufficient access to computers or devices to support AI-based instruction.	3.52	0.91	Accepted
3	AI tools often malfunction or are difficult to use due to technical issues.	2.78	1.05	Rejected
4	Lack of technical support affects the successful integration of AI tools.	3.48	0.94	Accepted
5	Lecturers are not adequately trained to implement AI tools in chemistry teaching.	3.41	0.97	Accepted
6	Curriculum limitations restrict the effective integration of AI tools.	3.33	0.88	Accepted
7	Large class sizes make it difficult to use AI tools effectively in teaching.	2.95	1.08	Rejected
	Cumulative Mean	3.30		Accepted

Benchmark: Mean ≥3.0 = Accept; Mean < 3.0= Reject

The results indicate that **key infrastructural challenges exist** in implementing AI tools (Reelmind.ai) in chemistry instruction at the Federal University of Education, Zaria, with a cumulative mean of 3.30, surpassing the benchmark. This benchmark (Mean ≥ 3.0) was adopted in line with the mid-point of the 5-point Likert scale, where a mean score of 3.0 represents a neutral response. Scores above this point were interpreted as agreement or positive perception, while those below indicated disagreement or negative perception. Respondents agree that unreliable internet, limited access to devices, lack of technical support, inadequate lecturer training, and restrictive curricula are significant obstacles. However, **technical malfunctions of AI tools and large class sizes** were not widely perceived as major barriers, as these items fell below the acceptance threshold. This suggests that while some infrastructural and human capacity issues are pressing, others such as the tools' stability and class size, may not be as critical or may vary by context. Addressing the highlighted challenges would enhance the integration and effectiveness of AI in chemistry education.

Table 4: What are the perceptions of chemistry lecturers and students regarding the use of AI tools (Reelmind.ai) in chemistry instruction at the Federal University of Education, Zaria?

S/N	Items	X	S.D	Remark
1	AI tools are useful for teaching and learning abstract chemistry concepts.	3.45	0.86	Accepted
2	I enjoy using (or learning through) AI tools during chemistry lessons.	2.87	1.12	Rejected
3	The use of AI in chemistry instruction motivates me to learn or teach better.	2.94	1.08	Rejected
4	I believe AI tools can replace some traditional laboratory activities effectively.	3.33	0.91	Accepted
5	I feel AI tools are too complicated to use for regular classroom activities.	2.76	1.09	Rejected
6	Using AI tools has improved my problem-solving or teaching strategies in chemistry.	2.89	1.04	Rejected
7	I would recommend the continuous use of AI tools in chemistry instruction.	3.22	0.88	Accepted
	Cumulative Mean	3.07		Accepted

Benchmark: Mean ≥3.0 = Accept; Mean < 3.0= Reject

The findings show a **generally positive perception** of AI tools (Reelmind.ai) among chemistry lecturers and students, with a cumulative mean score of **3.07**, which is above the acceptance threshold. Respondents particularly acknowledged the usefulness of AI tools in understanding abstract concepts, their potential to supplement laboratory work, and supported their continued use. This benchmark (Mean ≥ 3.0) was adopted in line with the mid-point of the 5-point Likert scale, where a mean score of 3.0 represents a neutral response. Scores above this point were interpreted as agreement or positive perception, while those below indicated disagreement or negative perception. However, **several items were rejected**, suggesting mixed feelings: enjoyment, motivation, ease of use, and impact on problem-solving or teaching strategies were rated lower. This implies that although AI tools are appreciated for their educational value, more needs to be done to improve **user experience, ease of adoption, and demonstrable impact** on teaching and learning outcomes to boost acceptance and engagement.

Discussion

The finding that there is a generally positive perception of the impact of AI tools (Reelmind.ai) on students' understanding of abstract chemistry concepts (X = 3.14) at the Federal University of Education, Zaria aligns with global trends in educational research. For instance, Pedaste et al. (2021) and Zawacki-Richter et al. (2019) emphasized that AI tools such as virtual laboratories and adaptive learning platforms enhance visualization, foster interactivity, and support personalized learning in science education. Similarly, Muhammad et al. (2022) found that virtual simulations significantly improved students' understanding of chemical bonding, a topic often considered abstract and challenging. Furthermore, Obichili and Ekwueme (2023) reported a 27% increase in chemistry achievement scores among Nigerian students taught with AI tools, validating the positive perception observed in this study. The result showing that lecturers at the Federal University of Education, Zaria possess high levels of Technological Pedagogical Content Knowledge (TPACK) (X = 3.13) is a strong indicator of their capacity to integrate AI into chemistry instruction effectively. This supports the view of Mishra and Koehler (2021), who assert that TPACK is essential for meaningful technology integration in education, particularly in STEM subjects. Likewise, Shulman (2015) emphasizes the intersection of content knowledge, pedagogy, and technology as key to innovative instruction.

Furthermore, Adebayo and Ibrahim (2024) noted that the success of AI-enhanced learning is closely tied to teacher competence in using these tools. However, other studies caution that high self-reported TPACK does not always translate into actual classroom practice, particularly where infrastructure or policy support is weak. For example, Yusuf and Balogun (2019) found that while Nigerian teachers often claim high technological knowledge, their ability to implement these skills effectively is hampered by limited institutional support and professional development opportunities.

The finding that key infrastructural challenges exist in implementing AI tools (Reelmind.ai) in chemistry instruction (X = 3.30) is consistent with numerous studies highlighting infrastructural deficits as a critical barrier in Nigerian education. Okonkwo et al. (2022) and Yusuf and Balogun (2019) have shown that inadequate internet access, erratic electricity supply, lack of functional devices, and poor technical support are common challenges in deploying educational technologies. Even in states with forward-looking initiatives such as the Kaduna Smart Schools Project, Ibrahim and Aminu (2023) found that only 18% of schools in Northern Nigeria had implemented AI-based tools, and primarily in urban areas. This infrastructural gap is further compounded by disparities in digital literacy and financial resources. While Hwang et al. (2020) argue that AI tools can improve access to high-quality education, their effectiveness is significantly diminished in poorly resourced environments. This highlights the need for context-sensitive solutions and sustained investments in educational infrastructure to support AI deployment. Lastly, the finding that there is a generally positive perception of AI tools (Reelmind.ai) among chemistry lecturers and students (X = 3.07) echoes national and international evidence of growing enthusiasm for digital learning innovations.

Olanrewaju et al. (2022) reported improved student engagement and conceptual understanding following the use of AI-powered virtual labs in Nigerian secondary schools, with both teachers and students showing strong support for these innovations. Likewise, Adedoyin and Soykan (2020) observed that the global shift towards technology-enhanced learning during the COVID-19 pandemic increased openness toward digital tools among educators. However, Etiubon and Udoh (2017) and Orji and Ebenezer (2021) noted that despite the positive perception, chemistry instruction in Nigeria continues to struggle due to systemic barriers including low digital literacy, cultural resistance, and inadequate follow-up training. This suggests that while the perception is favorable, it must be supported by practical enablers such as teacher development, curriculum integration, and institutional policy alignment for AI tools to be sustainably adopted.

Conclusion

This study investigated the effectiveness and implementation challenges of Artificial Intelligence (AI) tools (Reelmind.ai) in enhancing chemistry instruction at the Federal University of Education, Zaria. The findings revealed that both lecturers and students hold generally positive perceptions of AI tools, particularly in their ability to simplify abstract chemistry concepts, increase student engagement, and support personalized learning. Additionally, the study found that lecturers possess a relatively high level of Technological Pedagogical Content Knowledge (TPACK), suggesting a readiness to adopt AI-based instructional strategies. However, the study also identified significant infrastructural and contextual barriers, such as inconsistent power supply, limited internet access, and inadequate technical support that hinder the effective integration of AI tools in the teaching and learning process. Despite these challenges, the increasing acceptance of AI technologies and ongoing education reforms in Kaduna State provide a promising platform for further integration of AI into higher education. To maximize the benefits of these tools, institutional support, professional development, and policy alignment are essential. Effective implementation of AI in chemistry instruction requires a holistic approach that addresses not only technical and infrastructural needs but also human capacity, curriculum integration, and context-specific realities. The insights from this study offer a roadmap for education stakeholders aiming to leverage AI for improved science education outcomes in similar tertiary institutions across Nigeria.

Recommendations

1. The university administration and government agencies should invest in stable internet connectivity, reliable electricity, and access to up-to-date hardware and software.
2. Regular training and workshops should be organized to build and update lecturers' TPACK, particularly in the use of AI-powered educational tools.
3. University management and curriculum developers should ensure that AI tools (Reelmind.ai) are not treated as supplementary add-ons but are embedded within the chemistry curriculum.
4. Efforts should be made to ensure that all departments not just chemistry benefit from AI integration in the University.

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