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IMPACT OF GENERATIVE ARTIFICIAL INTELLIGENCE ON CHEMISTRY STUDENTS IN GOVERNMENT SCIENCE SECONDARY SCHOOLS, FEDERAL CAPITAL TERRITORY (FCT), ABUJA, NIGERIA

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Abstract

This study investigated the role of generative Artificial Intelligence (AI) in transforming chemistry education in Federal Capital Territory (FCT) government science secondary schools. A survey design was adopted, with seven research questions and two hypotheses tested at 0.05 level of significance. Structured questionnaires were administered to 103 students from Government Science Secondary School, Pyakasa, and Government Girls Science Secondary School, Kuje, and 15 chemistry teachers. Data were analysed using descriptive statistics and an independent t-test. Findings revealed that generative AI tools positively influenced students' understanding of chemistry concepts and academic achievement. The t-test showed a statistically significant difference in academic achievement between students who

used generative AI tools and those who did not. Teachers unanimously rated AI tools as effective or very effective in enhancing instruction and increasing student engagement. However, inadequate training, technical disruptions, and limited access to resources were prominent challenges for both groups. Students expressed overwhelmingly positive attitudes toward AI-enhanced chemistry learning. Personalized feedback systems and interactive simulations were identified as the most effective AI tools. The study recommends improved infrastructure, comprehensive teacher training, and policy development for sustainable AI integration in Nigerian secondary school chemistry education.

Keywords: Generative AI, Chemistry Education, Academic Achievement, Teacher Perceptions, Transforming Chemistry.

Introduction

Generative Artificial Intelligence (GenAI), encompassing machine learning models that can generate text, images, and simulations from training data, is increasingly reshaping

educational practice globally (Iyamuremye et al., 2024). In chemistry education, these tools offer personalized learning, interactive simulations, virtual laboratories, and automated feedback, addressing long-

standing pedagogical challenges. Hao et al. (2024) demonstrated that AI-driven precision teaching significantly improved student academic achievement; Alhashem and Alfaiakawi (2023) found that AI-supported virtual laboratories enhanced conceptual understanding over traditional textbooks; while Altares-López et al. (2024) confirmed that AI tools boosted engagement and retention of complex chemistry content. In Nigeria, chemistry remains foundational to STEM pathways, yet secondary school performance is persistently poor (Olubunmi & Aarinola, 2022). FCT government science schools face resource scarcity, inadequate ICT infrastructure, and insufficient teacher training (Egbe, 2023; Jacob et al., 2020). Despite global advances, locally grounded research on generative AI in FCT schools remains scarce. This study investigated the role of generative AI in transforming chemistry learning in FCT government science secondary schools, examining impacts on student achievement, teacher perceptions, challenges, student attitudes, and the effectiveness of specific AI tools. The study is anchored on three theoretical frameworks: Constructivist Learning Theory (Piaget, 1976; Vygotsky, 1978), which posits that learners construct knowledge through experiential, technology-mediated engagement; Cognitive Load Theory (Sweller, 2023), which holds that AI tools reduce extraneous cognitive demands

through adaptive content segmentation and feedback; and the TPACK Framework (Feldman-Maggor et al., 2024), which emphasizes that effective technology integration requires intersecting teacher competencies in content, pedagogy, and technology.

Statement of the Problem

Many secondary school students continue to record poor outcomes in chemistry due to the abstract nature of chemical concepts, limited laboratory resources, and inadequate engagement strategies. Generative AI offers solutions through personalised learning, simulations, and automated tutoring, yet its specific implications in FCT government schools and its impact on chemistry learning outcomes remain underexplored.

Research Questions

Seven research questions guided the study:

1. How does generative AI affect students' academic achievement in chemistry?
2. What are teachers' perceptions of AI integration in teaching?
3. (a/b) What challenges do students and teachers face in using generative AI?
4. What are students' attitudes towards generative AI in chemistry?

5. (a/b) What specific AI tools are most effective from students' and teachers' perspectives?

Hypotheses

Two hypotheses were tested at 0.05 level of significance.

- H₀₁. Students using generative AI tools will show significantly higher academic achievement than those who do not.
- H₀₂. Chemistry teachers will perceive the integration of generative AI as beneficial for teaching and classroom engagement.

Review of Literature

Generative AI, including GANs, VAEs, and transformer models such as GPT-4, enables adaptive content generation, real-time feedback, and interactive simulations that support personalized chemistry instruction (Yenduri et al., 2023). Akbar and Djakariah (2024) demonstrated that AI-driven simulations significantly improved students' visualization of molecular interactions. Deng et al. (2023) demonstrated that tools such as ChatGPT support both teachers and students by providing instant explanations, generating assessments, and assisting with research. Almasri (2024) confirmed that AI-enhanced platforms support personalized assessment and content adaptation, while cautioning that cost, privacy, and ethical concerns remain significant barriers in developing contexts.

Implementation challenges in Nigeria are well-documented. Egbe (2023) and Jacob et al. (2020) identified inadequate ICT infrastructure- unreliable electricity and poor internet- as the foremost barrier. Osasona et al. (2024) raised ethical concerns around data privacy and algorithmic bias, while Selwyn (2024) and Folashade et al. (2023) highlighted educator resistance and limited resources as compounding obstacles, particularly in FCT public schools.

Methodology

A survey research design was employed. The target population comprised all chemistry students and teachers in FCT government science secondary schools. Two schools were purposively selected: Government Science Secondary School (GSSS), Pyakasa (urban), and Government Girls Science Secondary School (GGSSS), Kuje (rural). A total of 103 students (53 from GSSS Pyakasa; 50 from GGSSS Kuje) and all 15 available chemistry teachers from both schools were sampled, for a total of 118 participants.

A structured questionnaire comprising 18 items across seven sections covering AI impact on student performance, teacher perceptions, challenges, student attitudes, and AI tool effectiveness was the primary instrument. Validity was established through expert review by four specialists. Reliability was confirmed through a pilot test on

students and teachers from schools outside the study. Data were analysed in JASP using descriptive statistics (frequencies, percentages, means) and an independent t-test for hypothesis testing at $\alpha = 0.05$.

Results

Research Question 1: Impact on Students' Academic Achievement

Table 1: Frequency of Student Use of Generative AI Tools in Chemistry Classes

Never 25 (24.3%)	Rarely 12 (11.7%)	Sometimes 14 (13.6%)	Often 32 (31.0%)	Always 20 (19.4%)
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Note. n = 103. SD = Strongly Disagree; D = Disagree; A = Agree; SA = Strongly Agree.

Table 1 shows 31.0% of students used generative AI tools often and 19.4% always, with only 24.3% never using them, indicating substantial AI access and uptake.

Table 2: Student Rating of How Generative AI Affects Understanding of Chemistry Concepts

Much Worse 2 (1.9%)	Worse 2 (1.9%)	No Change 0 (0%)	Better 55 (53.4%)	Much Better 44 (42.7%)	Total 103
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Note. n = 103.

Table 2 shows 96.1% of students reported better or much better understanding of chemistry since using AI tools, with only 3.8% reporting negative effects.

Table 3: Student Agreement on Improvement in Chemistry Test Scores Since Using Generative AI Tools

SD 5 (4.8%)	D 12 (11.7%)	Neutral 0 (0%)	A 46 (44.7%)	SA 40 (38.8%)	Total 103
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Note. n = 103. SD = Strongly Disagree; D = Disagree; A = Agree; SA = Strongly Agree.

As shown in Table 3, 83.5% of students agreed or strongly agreed that their test scores improved since using generative AI tools.

Research Question 2: Teachers' Perceptions

Table 4: Teacher Rating of Effectiveness of Generative AI Tools in Enhancing Teaching Methods

Very Ineffective 0 (0%)	Ineffective 0 (0%)	Neutral 0 (0%)	Effective 9 (60%)	Very Effective 6 (40%)
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Note. n = 15.

All 15 teachers (100%) rated AI tools as effective (60%) or very effective (40%) in enhancing teaching — a unanimous endorsement.

Table 5: Teacher Assessment of How Generative AI Affected Student Engagement

Sig. Decreased 0 (0%)	Decreased 0 (0%)	No Change 0 (0%)	Increased 12 (80%)	Sig. Increased 3 (20%)
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Note. n = 15.

Table 5 shows all teachers reported increased (80%) or significantly increased (20%) student engagement through AI tool use.

Table 6: Teacher Agreement on Feeling Adequately Trained to Use Generative AI Tools

SD 4 (26.7%)	D 9 (60%)	N 0 (0%)	A 2 (13.3%)	SA 0 (0%)	Total 15
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Note. n = 15. SD = Strongly Disagree; D = Disagree; N = Neutral; A = Agree; SA = Strongly Agree.

Despite positive perceptions, 86.7% of teachers disagreed or strongly disagreed that they felt adequately trained, revealing a critical professional development gap.

Research Questions 3a & 3b: Challenges

Table 7: Challenges Encountered by Students in Using Generative AI Tools for Chemistry Learning

Challenge	Frequency (%)
Lack of training	40 (38.8%)
Technical issues	26 (25.2%)
Resistance to change	20 (19.4%)
Limited resource access	17 (16.6%)
Total	103 (100%)

Note. n = 103.

Table 8: Challenges Encountered by Teachers in Using Generative AI Tools in Teaching Chemistry

Challenge	Frequency (%)
Lack of training	5 (33.3%)
Technical issues	4 (26.7%)
Limited resource access	4 (26.7%)
Resistance to change	2 (13.3%)
Total	15 (100%)

Note. n = 15.

Tables 7 and 8 reveal that a lack of training was the foremost challenge for both students (38.8%) and teachers (33.3%), followed by

technical issues and limited access to resources, pointing to systemic infrastructural and capacity deficiencies.

Research Questions 4 & 5: Student Attitudes and Effective AI Tools

All 103 students expressed positive attitudes (61.2%) or very positive attitudes (38.8%) towards generative AI in chemistry. All students agreed (52.4%) or strongly agreed (47.6%) that AI makes chemistry more

interesting and engaging. Personalized feedback systems were identified as most effective by both students (43.7%) and teachers (33.3%), followed by interactive simulations (students: 23.3%; teachers: 26.7%).

Hypotheses Testing

Table 9: Difference in Academic Achievement Between Students Who Use and Do Not Use Generative AI Tools

Group	N	Mean	SD	t	p
Students using generative AI tools	80	22.64	7.42	2.81*	< .05
Students not using generative AI tools	23	19.88	8.87		

*Note. *p < .05; df = 101, critical t = 1.960.*

The calculated t-value (2.81) exceeded the critical value (1.960), so H01 was rejected. Students using generative AI tools recorded significantly higher mean scores (22.64) than non-users (19.88), confirming AI use is associated with improved chemistry achievement.

Table 10: Difference in Teachers' Perceived Benefit of Generative AI Integration

Group	N	Mean	SD	T	p
Teachers: high AI perception	9	5.43	1.24	0.39	> .05
Teachers: low AI perception	5	3.19	1.78		

Note. $df = 13$, critical $t = 2.160$.

The calculated t-value (0.39) was less than the critical value (2.160), so H02 was accepted. No statistically significant difference existed between teachers with high and low AI perceptions, indicating uniformly positive views across the teacher group.

Discussion

The significant difference in academic achievement between AI users and non-users ($t = 2.81$, $p < .05$) aligns with Hao et al. (2024) and Okunade (2024), who established that personalized AI-mediated learning fosters greater retention of chemistry knowledge. The near-universal improvement in conceptual understanding (96.1%) corroborates Altares-López et al. (2024), whose research found that adaptive, interactive AI tools are particularly effective for abstract chemistry content.

Teachers' unanimous endorsement of AI tools for instruction and engagement is consistent with the findings of Deng et al. (2023) and Almasri (2024). However, the training deficit — identified by 86.7% of teachers and 38.8% of students as a primary challenge — echoes Egbe (2023) and Osasona et al. (2024), who warned that unrealised potential is the inevitable outcome where capacity building is absent. Technical disruptions reflect Jacob et al.'s (2020)

finding that poor ICT infrastructure remains foundational in Nigerian schools. The unanimous positivity of student attitudes aligns with Baidoo-Anu and Ansah (2023), who found that AI-driven learning environments foster strong student motivation. The acceptance of H02 — indicating no significant difference between high and low AI-perception teachers — suggests that the teaching community is broadly ready to embrace AI, contingent on removing structural barriers.

Conclusion

Generative AI tools significantly enhance chemistry students' academic achievement and are positively perceived by students and teachers in FCT government science secondary schools. However, training inadequacies, infrastructural limitations, and policy gaps present significant barriers to sustainable integration. A multi-stakeholder approach encompassing government infrastructure investment, teacher

professional development, and evidence-based policy formulation is essential for harnessing AI's transformative potential in Nigerian chemistry education.

Recommendations

Based on the findings, this study recommends that:

- (1) The FCT government prioritize investment in reliable electricity and internet infrastructure;
- (2) Comprehensive, context-specific teacher training programmes on generative AI integration should be developed and implemented;
- (3) Schools explore partnerships with technology companies for AI implementation funding; (4) clear national policies on data privacy and ethical AI use in schools should be formulated;
- (4) Awareness campaigns targeting all stakeholders should be launched; and
- (5) The chemistry curriculum should be revised to incorporate AI-assisted methods, with pilot programmes preceding wider rollout.

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