



Effects of Artificial Intelligence Enriched Inquiry-Based Strategy on Performance in Chemistry among Secondary School Students in Zaria Metropolis, Kaduna, Nigeria

Ahmad Muazu Ahmad^{1*}, Ramatu Ematum Umahaba², Yusuf Feyisara Zakariya² and Muhammad Umaru Saidu³

¹Department of Chemistry, Jigawa State College of Education, Gumel, Jigawa State, Nigeria

²Department of Science Education, Ahmadu Bello University, Zaria, Kaduna State, Nigeria

³Institute of Education, Ahmadu Bello University, Zaria, Kaduna State, Nigeria

*Corresponding author: muazuahmad03@gmail.com

Abstract

This study investigated the effects of ChatGPT enriched inquiry-based strategy (IBS+ChatGPT) on secondary school students' performance in Chemistry. A quasi-experimental pretest–posttest group design was adapted. A sample of 103 (63 in experimental and 40 in control groups) secondary students were randomly selected from a population of 7,116 students across 17 public schools in Zaria. The experimental group was taught using IBS+ChatGPT while the control was taught using the conventional method. Data were collected using the chemical reaction and equilibrium performance test (CREPT), which was validated and yielded a reliability coefficient of .85. Two research questions and two hypotheses were formulated to guide the study. The research questions were answered using mean, standard deviation and bar charts. The hypotheses were tested at $\alpha=.05$ level of significance using analysis of covariance (ANCOVA) with pretest performance scores as a covariate. The result showed no significant difference in students' performance between the experimental ($M=51.08$, $SD=11.716$) and control ($M=39.20$, $SD=10.493$) groups, $F(df)=103$, $p=.068$. That is, there was an improved performance of students taught using the IBS+ChatGPT as compared to those taught using the conventional method after accounting for the initial differences between the two groups. However, there was no sufficient evidence to claim this improved performance is not due to random errors. Further, the result showed no significant difference in the performance of male ($M=53.61$, $SD=11.093$) and female ($M=46.36$, $SD=11.623$) students taught using IBS+ChatGPT, $F(df)=63$, $p=.385$ indicating that the IBS+ChatGPT was gender friendly. It was recommended that future studies should use a longer treatment period to better determine the effectiveness of the strategy.

Keywords: artificial intelligence, chemistry education, conventional method of teaching, gender, inquiry-based strategy, student's academic performance

1 Introduction

The introduction should be succinct and contain no subheadings. This section should present background for the study, Chemistry, as a core science subject taught in Senior Secondary Schools in Nigeria, is recognized as fundamental to scientific and technological development. It deals with the study of matter, its structure, composition, properties, and the changes it undergoes (Awodun et al., 2024). Chemistry education contributes significantly to various sectors, including agriculture, healthcare, and industry, by providing the necessary knowledge and skills for innovation and problem-solving (Raman et al., 2024). A solid foundation in chemistry is crucial for future opportunities, scientific literacy, and national development (Dauda and Shoge, 2024). Chemistry is intertwined with everyday life, as humans constantly interact with and use chemical products such as cosmetics, drugs, detergents, soaps, fertilizers, and insecticides. The technology behind these products requires a basic knowledge and application of chemistry. Therefore, equipping students with the skills needed to address real-world challenges is essential (Chikendu et al., 2021). The assertion that Chemistry is the bride of science, according to (Selvarasu, 2023; Umahaba, 2016) is based on the pivotal role that Chemistry plays in industrial establishments and also in other professional disciplines such as Engineering, Agriculture, and Medicine. Despite the significance of chemistry in national development, the academic performance of Nigerian secondary school students in the subject has remained subpar, raising national concerns (Agu & Okafor, 2021). In this study, academic performance is the outcome of a test given to students by the researcher before and after administration of treatment aimed at determining the effect of the ChatGPT enriched Inquiry-based strategy (ChatGPT +IBS) in learning Chemistry. Studies attribute this trend

to several factors, including the abstract nature of Chemistry concepts, students' attitudes, and ineffective teaching methodologies. Awodun et al. (2024) identify the conventional teaching methods used in secondary schools as responsible for producing learners who can verbally explain concepts but cannot demonstrate scientific applications. Oladejo (2022) highlights that students find concepts like chemical reactions, equilibrium, and redox reactions particularly challenging, and teaching these topics through conventional methods further hinders academic performance. To improve students' academic performance, it is imperative to address these issues through curriculum reform, targeted teacher training, and the adoption of effective teaching methodologies. A reformed curriculum should integrate, hands-on experiments and real-world applications, to effectively enhance student performance through an IBS.

IBS has gained prominence as an effective pedagogical approach, particularly in science education. It engages students through questioning, exploration, and problem-solving, fostering deeper comprehension and retention of scientific concepts (Danjuma and Mankilik, 2022). IBS addresses the limitations of conventional teaching methods, which often produce learners who can explain scientific concepts verbally but cannot demonstrate them practically. By encouraging students to construct knowledge actively, IBS promotes critical thinking, analytical skills, and greater engagement (Ntibi and Neji, 2021). It provides opportunities for active participation, which improves students' performance in chemistry. Several models of IBS exist in the literature which include Bybee et al. (2006) 5E learning Cycle Model, Heather's Seven Steps IBS Model, Zakariya's (2025) model of Inquiry-Driven Collaborative Learning (IDCL). For this study Zakariya's (2025) IDCL model was adapted because is an innovative framework designed to foster productive learning, particularly among Generation Z students in mathematics and science education. This model aims to bridge the gap between inherently high-achieving students and those requiring more structured support to reach desired learning outcomes. The IDCL model integrates both inquiry-based and collaborative learning strategies, structuring lessons into two key segments: direct instruction and activity-based learning. The direct instruction component delivers foundational knowledge and can incorporate various modalities, including face-to-face learning, virtual learning, and pre-recorded videos that students can access before and after each lesson. The activity-based lesson segment, as outlined in the IDCL model by Zakariya (2025), is a crucial part of the lesson structure designed to actively engage students and foster productive learning

Given the proliferation of Artificial Intelligence (AI) in education, some researchers (e.g., Erno and Berry, 2025; Zhang and Li, 2024) have integrated AI + IBS and found some positive effects on students learning outcomes. AI involves developing computer systems capable of performing tasks that require human intelligence, such as learning, reasoning, and problem-solving (Russell and Norvig, 2016). According to Kaplan and Haenlein (2019), AI employs algorithms and software to replicate human cognitive abilities. Recent advancements in generative AI, particularly models like ChatGPT, have highlighted AI's transformative potential across various sectors, including education (Hong et al., 2022; Lucci et al., 2022). Unlike predictive AI, which focuses on data-driven forecasting, generative AI creates new content, such as text, images, and code through deep learning (Tang and Cooper, 2024). In education, Generative AI tools like ChatGPT, Grammarly, Quizlet AI, and Khanmigo are revolutionizing learning by offering personalized feedback, adaptive support, and real-time guidance. Among these, ChatGPT is valuable for secondary school students, because it provides explanations, problem-solving steps, and essay-writing assistance that foster understanding, critical thinking, and independent learning. Student-centered approaches further enhance this process by integrating AI into IBS, enabling learners to explore concepts more deeply and develop cognitive skills through individualized learning experiences (Zhang and Li, 2024). AI plays a crucial role in chemistry education, where abstract concepts often challenge students. By scaffolding learning in line with Bruner's theory, AI can reduce cognitive load and improve engagement (Zhang and Li, 2024). Tools like ChatGPT and interactive simulations help students visualize complex reactions, analyze data, and apply concepts effectively. However, despite the proven potential of IBS, its integration with AI remains underexplored in Nigerian chemistry classrooms. This study will examine how an AI + IBS can bridge performance gap, particularly concerning gender disparity.

Gender refers to the socially constructed roles and responsibilities assigned to men and women in a given culture or location, according to the Global Education Monitoring Report Team (2022), gender remains a critical variable in science education, particularly in subjects like chemistry, where performance disparities may arise due to social and psychological factors. In Nigerian senior secondary schools, traditional gender roles have historically influenced expectations and participation in science classrooms. According to Ejilibe et al., (2020) IBS, which emphasize active student involvement through exploration, questioning, and experimentation, have been shown to enhance both male and female students understanding of complex Chemistry concepts. However, IBS alone may not be sufficient, especially when students face cognitive overload or lack personalized support. In this instance, IBS+ChatGPT has emerged as a potential solution, offering adaptive learning pathways, real-time feedback, and increased students' engagement. Tools like ChatGPT and other AI applications can simulate inquiry-based environments that support learners in understanding abstract Chemistry concepts. As such, the

purpose of this study is to investigate the effect of IBS+ChatGPT on performance in chemistry among secondary school students in Zaria metropolis, Kaduna State, Nigeria.

In specific terms, the objective of this study is twofold: (1) to determine the effects of IBS+ChatGPT on performance in Chemistry among secondary school students in Zaria Metropolis, Kaduna State, Nigeria; (2) to determine the effects of IBS+ChatGPT on performance in chemistry among male and female secondary school students in Zaria Metropolis, Kaduna State Nigeria. The specific objectives were further operationalized and probed through the following research questions:

1. What is the difference between the mean academic performance scores of secondary school students taught Chemistry with ChatGPT + IBS and students taught with the conventional method?
2. What is the difference between the mean academic performance scores of male and female secondary school students taught Chemistry with ChatGPT + IBS?

Addressing these research questions will provide evidence on effectiveness of the ChatGPT + IBS in improving students' academic performance in chemistry compared with the conventional teaching method. The outcomes will also determine whether the strategy benefits male and female students equally, thereby providing insights in to gender inclusiveness. The findings will also assist teachers, school administrators, curriculum developers and policymakers in making informed decisions regarding the integration of ChatGPT+ IBS into chemistry instruction and will contribute to the growing body of literature on ChatGPT supported teaching and learning. This manuscript is divided into sections. Section two presents a theoretical framework, encompassing theoretical foundations, prospect, critique and limitation of the theories, follow by section Three describes the methodological procedures adopted for the study, including the research design, target population, sampling techniques, research instruments, IDCL model, methods of data collection, and procedures employed for data analysis. In section four result and interprets the findings obtained from the analyzed data. However, section five provides a comprehensive discussion of the findings and finally section six provides conclusion and recommendation of the study

2 Theoretical Framework

This study was anchored on Bruner's theory of learning (1961). Bruner's theory of learning, developed in the 1960s during the cognitive revolution, challenged behaviorist assumptions by proposing that learning is an active process in which learners construct meaning from their experiences. His work emphasized that understanding develops through mental activity rather than passive reception. Bruner identified three modes of representation, enactive, iconic, and symbolic, which describe how learners move from concrete action to visual understanding and finally to abstract reasoning. He also introduced the spiral curriculum, arguing that concepts can be taught at any age if appropriately structured and revisited with increasing level of complexity. Equally central is scaffolding, where learners receive temporary support that is gradually withdrawn as their competence grows. Bruner's belief in discovery learning emphasizes the value of inquiry, problem-solving, and exploration in promoting meaningful learning. Bruner's ideas align strongly with IBS because both emphasize that knowledge is constructed through active engagement. In IBS, students investigate, question, and interpret information, reflecting Bruner's principles of guided discovery and mental model formation. The connection becomes evident in the idea that through the construction of knowledge, student performance improves due to deep engagement with content in learning process. As learners explore and make sense of content, their understanding strengthens, leading to higher achievement.

The theory also resonates with the growing use of AI, particularly tools like ChatGPT. AI can provide scaffolding by offering explanations, prompting inquiries, suggesting alternatives, and clarifying misconceptions. It supports multiple modes of representation and allows learners to revisit concepts at increasing levels of complexity, reflecting Bruner's spiral curriculum. By enabling students to ask questions and construct meaning interactively, AI fosters deep engagement that enhances students' performance. Building on these theoretical postulations, it is expected that when students, regardless of their gender, are taught using IBS+ChatGPT their performance in chemistry will improve. Thus, we hypothesise that:

H₀₁: There will not be a significant difference in the mean performance scores of secondary school students taught chemistry with IBS+ChatGPT and those taught using the conventional method.

H₀₂: There will not be a significant difference in the mean performance scores of male and female secondary school students taught chemistry using IBS+ ChatGPT.

We acknowledge that despite its significant impact of Bruner's learning theory in the field of psychology and its associated fields, it has equally faced criticisms. Some argue that discovery learning can confuse beginners when guidance is inadequate (Sweller, 2023), while others note that scaffolding requires significant teacher expertise and time. The theory's broad nature also poses challenges for empirical testing (Taber, 2024). Nevertheless, its prospects remain strong. Modern emphasis on critical thinking, inquiry-based, and learner-centered teaching as well as advancements in AI continue to reinforce Bruner's ideas (Krishna et al. 2024), keeping his theory highly relevant in contemporary education.

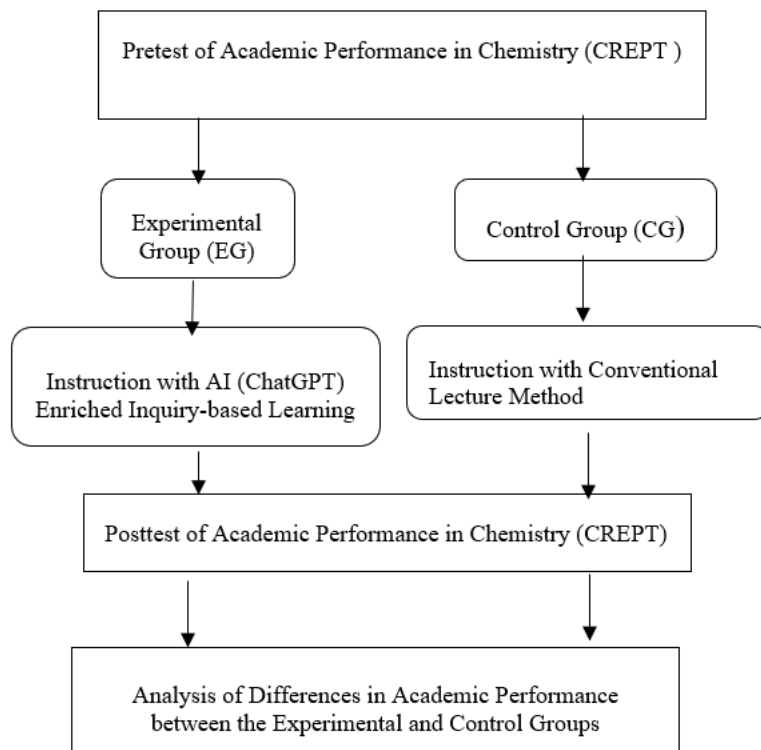
3 Methodology

3.1 Research Design

This study adopts a quasi-experimental pre-test–post-test control group design, involving two groups: an experimental group and a control group. A defining feature of the quasi-experimental design is the absence of random assignment of participants to groups. Instead, intact classes were used to maintain existing school structures and classroom dynamics, thereby enhancing the study feasibility. Before the intervention, a pretest was administered to all participants to assess their baseline academic performance in Chemistry. Thereafter, the experimental group was taught using ChatGPT + IBS, while the control group received instruction through the conventional lecture method. Both groups cover the same Chemistry concepts of Chemical reaction and Equilibrium for a period of three weeks. The concepts are relatively abstract and require learners to understand processes that are not always directly observable, such as the rearrangement of particles during chemical reactions and the dynamic nature of equilibrium. At the end of the instructional period, a posttest was administered to evaluate the effect of an AI (ChatGPT) + IBS on students' academic performance in Chemistry. The research design is diagrammatically presented Figure 1.

Figure 1

Research design



Where:

CREPT = Chemical Reaction and Equilibrium Performance Test; Experimental Group (EG); Control Group (CG)

The target population for this study comprises all Senior Secondary II (SSII) students offering Chemistry in public senior secondary schools within Zaria Metropolis, Kaduna State, Nigeria. There are seventeen (17) public senior secondary schools in the metropolis. Of these, seven (7) are single-sex schools, while ten (10) are co-educational schools. The total number of SSII Chemistry students across these schools is 7,116, comprising 3,352 males and 3,764 females. For this study, only co-educational schools were considered. This decision is informed by the need to control for gender as a covariate, since the study aims to explore how the ChatGPT + IBS affects male and female students differently

3.2 Participant

A sample of 103 participant SSII students from two co-educational secondary schools in Zaria Metropolis, Kaduna state, Nigeria was selected using simple random sampling technique.

Participant of the Study

Groups	Male	Female	Number of participants
Experiment	22	41	63
Control	14	26	40
Total	36	67	103

3.3 Instrumentations

Chemical Reaction and Equilibrium Performance Test (CREPT) was used for data collection, the questions were adopted from WAEC and NECO past questions papers from 2015 to 2021 by the researcher, drawing directly from the relevant content areas. The CREPT consists of twenty-five multiple-choice questions designed to assess both lower-order and higher-order thinking skills, in alignment with Bloom's Taxonomy (1956).

3.4 Validation of the Instrument

In an attempt to establish the validity of the instruments, the instruments were subjected to scrutiny, which was achieved by presenting the instruments to a panel of experts comprising: One Senior Lecturer from the Department of Chemistry, Ahmadu Bello University, Zaria, another Senior Lecturer from the Department of Science Education, Federal University, Dutsin-Ma, Katsina State and one Secondary School Chemistry teacher from Barewa College, with a qualification of BSc.Ed, all validated the quality, comprehensive, adequate, relevant of the instrument to the study. Some Suggestions for improving the Chemical Reaction and Equilibrium Performance Test (CREPT) include replacing "Predict" with "Balance" in all the items, removing additional explanations from the options, and using simplified language to avoid ambiguity.

3.5 Reliability of the Instruments

After the pilot testing, the items were analyzed using difficulty and discrimination indices to determine the items to be retained. The retained items were subsequently subjected to Pearson Product Moment Correlation (PPMC) to determine the reliability of the test items. The reliability of the instrument was found to be .85, which indicate high correlation between the test items. The result obtained therefore shows the suitability of the test item for the study.

3.6 IDCL model

The experimental group was taught Chemical Reaction and Equilibrium using the ChatGPT + IBS for three (3) weeks. Each lesson lasted for 80 minutes. The lesson plan was based on the IDCL Model, adapted from Zakariya (2025). During the lessons, students took part in inquiry-based activities and used ChatGPT to explore topics, ask questions, get explanations, and understand ideas better. A pre-test was given before the lessons started, and a post-test was also given after the three-week lessons. In each lesson, the teacher presents the learning outcomes. Then, the teacher explains to students what ChatGPT is and how they will use it. This step was followed by teacher-led instruction for half of the period. In the second half, the students were assigned into groups randomly. Each group was assigned a concept/task. In this activity part of the lesson, students used ChatGPT to ask/pose questions related to the assigned contents, explored examples and

answered the evaluation questions attached to the assigned portion of the note. Thereafter, students share findings and reflect on challenges and reasoning. In the last stage of the IDCL, the teacher evaluated group responses, facilitated deeper comprehension of the concept, and provided formative feedback to the students.

3.7 Procedure for Data Collection

After the period of intervention, the Chemical Reaction and Equilibrium Performance Test (CREPT) was administered by the researcher. Students selected the correct answers from the given options. A suitable test environment was ensured, with proper lighting, ventilation, and spacing. Instructions were read by the students and explained verbally when needed. Test duration followed the pilot testing timing. Completed responses were collected and recorded for analysis based on research questions and hypotheses.

3.8 Procedure for Data Analysis

The data collected was subjected to appropriate statistical analyses. The results were used to address the research questions and to test the null hypotheses at a significance level of $\alpha = 0.05$. To address the research questions, the data collected was analysed using descriptive statistics, specifically the mean, standard deviation and bar chart where hypotheses were tested using ANCOVA since the data met the parametric assumption. All analyses were conducted in the statistical package for social sciences software, version 20.

4 Results

The results were presented in alignment with the research questions and hypotheses

Addressing research question one and hypothesis one

To address the first research question, mean, standard deviation and bar chart was used to present the analysis of posttest performance scores of students taught using ChatGPT + IBS and those taught using Conventional Method of teaching. The result is presented in Figure 4.1.

Figure 4. 1

Summary statistics of post-test performance scores

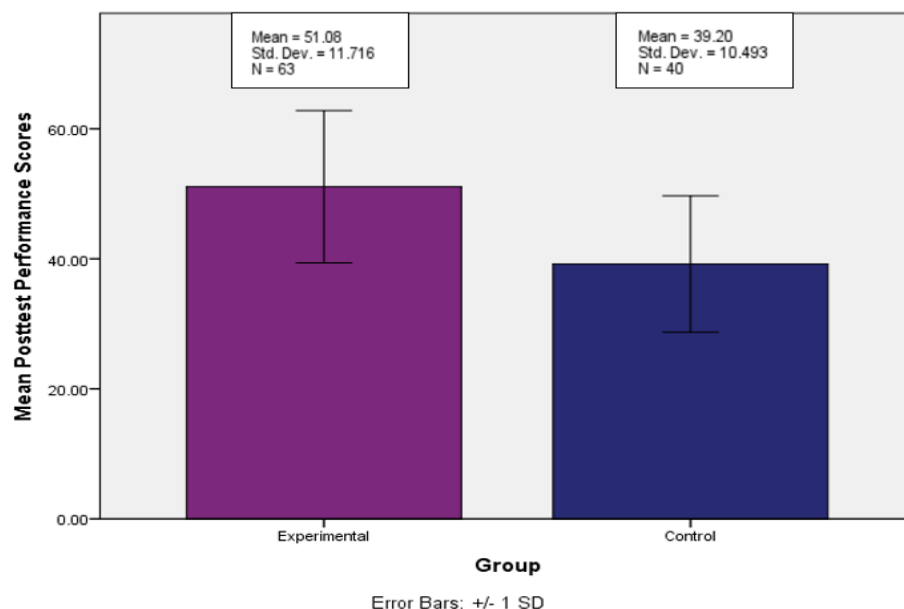


Figure 4.1 shows that the post-test mean of CREPT scores of the experimental group was 51.08 with a standard deviation 11.716 and the control group recorded post-test mean CREPT scores of 39.20 with standard deviation 10.493 respectively. Further, these results show that the means scores of students taught using ChatGPT + IBS is higher than those taught using the conventional method with a mean difference of 11.88. To investigate whether this obtained mean difference is significantly significant, we subjected the posttest performance scores to an inferential statistical test.

Prior to testing hypothesis, the post-test performance scores were subjected to the test of normality as a requirement for using parametric tests or otherwise. The results of this data exploration are presented in Table 4.1.

Table 4.1

Tests of Normality

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	p-value	Statistic	df	p-value
Post-test performance scores	.102	103	.011	.983	103	.196

a. Lilliefors Significance Correction

For the post-test performance scores, Table 4.1 shows that the Shapiro–Wilk test was not significant ($p > .05$), although the Kolmogorov–Smirnov test indicated non-normality ($p < .05$), suggesting a deviation from normality. Given the Shapiro–Wilk test's higher sensitivity for small to mid-sized samples, the assumption of normality was considered not violated. Therefore, a parametric test in the form of ANCOVA was used for testing hypotheses one and two using pre-test performance scores as the covariate. The ANCOVA results for testing hypothesis one are presented in Table 4.2.

Table 4.2

Summary of ANCOVA statistics for Performance Scores on Difference Between Experimental and Control groups

Source	Type III Sum of Squares	Df	Mean Square	F-value	p-value	Partial Squared	Eta
Corrected Model	11258.125 ^a	2	5629.062	112.592	< .001	.692	
Intercept	2485.092	1	2485.092	49.707	< .001	.332	
Pretest	7805.497	1	7805.497	156.125	< .001	.610	
Group	170.094	1	170.094	3.402	.068	.033	
Error	4999.506	100	49.995				
Total	238644.000	103					
Corrected Total	16257.631	102					

a. R Squared = .692 (Adjusted R Squared = .686)

Table 4.2 ANCOVA result shows that the pre-test performance scores between the experimental and control groups is significantly significant $F(1, 103) = 156.125$, $p < .001$. This shows that there was difference in the performance of students in both experimental and control groups before the intervention. Further, Table 4.2 shows that that the post-test performance scores between the experimental and control groups is not statistically significant $F(1, 103) = 3.402$, $p = .068$. That is, there is no significant difference between the mean academic performance score of students taught Chemical Reaction and Equilibrium with ChatGPT + IBS and those taught with conventional method after account for the initial differences in the performance of students before the intervention.

Addressing research question two and testing hypothesis two

To address the second research question, mean, standard deviation and bar chart were used to present the analysis of post-test performance scores of male and female students taught using ChatGPT+ IBS. The result is presented in Figure 4.3

Figure 4.2

Summary statistics of post-test performance scores of males and females

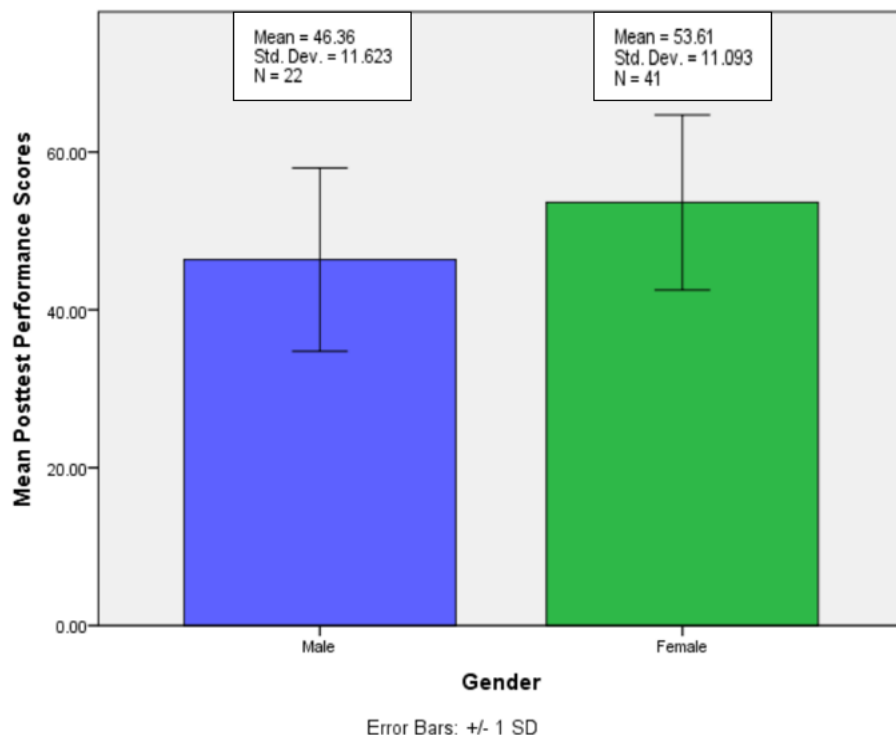


Figure 4.3 shows that the post-test mean performance scores of male and Female in the experimental group revealed that female students scored higher Mean 46.36 with Standard deviation 11. 623 than male students with mean 53.61 and Standard Deviation 11.093 respectively. Further, these results show that the means scores of Female students taught using ChatGPT + IBS is higher than those of Male students with a mean difference of 7.25. To investigate whether this obtained mean difference is significantly significant, we subjected the post-test performance scores to an inferential statistical test. The ANCOVA results for this analysis are presented in Table 4.5.

Table 4.5

Summary of ANCOVA statistics for male and female performance scores in Experimental Group

Source	Type III Sum of Squares	Df	Mean Square	F-value	p-value	Partial Squared	Eta
Corrected Model	6013.151 ^a	2	3006.576	72.231	<.001	.707	
Intercept	1311.682	1	1311.682	31.512	<.001	.344	
Pretest	5261.395	1	5261.395	126.402	<.001	.678	
Gender	31.904	1	31.904	.766	.385	.013	
Error	2497.452	60	41.624				
Total	172884.000	63					
Corrected Total	8510.603	62					

a. R Squared = .707 (Adjusted R Squared = .697)

Table 4.4 ANCOVA result shows that the pre-test performance scores between the male and Female is significantly significant $F(1, 103) = 126.402$, $p < .001$. This shows that there was difference in the performance of Male and Female students before the intervention. Further, Table 4.4 shows that the post-test performance scores between the Male and Female is not statistically significant $F(1, 103) = .766$, $p = .385$. That is, there is no significant difference between the mean academic performance score of Male and Female students taught Chemistry with ChatGPT + IBS after account for the initial differences in the performance of students before the intervention.

5 Discussion of Findings

The study investigated the effects of ChatGPT + IBS on Performance in Chemistry among Secondary School Students in Zaria Metropolis. Two research questions were answered, and two corresponding null hypotheses were raised and tested. The result showed that no significant difference exists in the academic performance scores of secondary school students taught using ChatGPT + IBS and those taught using the conventional method. This indicates that both the experimental and control groups performed at similar levels. The absence of a significant difference suggests that, although the ChatGPT + IBS encouraged active participation through tasks and discussions, it did not lead to a statistically higher performance than the conventional method within the study period. Both methods appeared equally effective in facilitating students comprehending of Chemical Reaction and Equilibrium concepts. This finding aligns with those of Sylvanus and Eke (2017), who reported that no significant difference in the performance of students taught with IBS compared to those taught with the conventional method. However, this result contradicts the finding of Tijani (2025), Ojelade et al. (2024), Danjuma and Mankilik (2022) and Odukwe and Nwafor (2021) whose reported that students taught using IBS significantly outperformed those taught using the traditional lecture method in academic achievement. Similarly, findings disagreed with findings of Erno and Berry (2025) reported that learning and development in science can be significantly accelerated by AI-driven tools, including Poll Everywhere, which will develop student knowledge compared with teaching using conventional instructional approach. Moreover Kotsis (2024) reported that including AI in the classroom prepares students for a technologically driven future which contradicts the findings of this study. Nevertheless, findings of the present study also diverge from that of Oyiza et al. (2025), Aregbesola et al. (2025), Akhtar et al. (2025), Nneka and Otarigho (2024) and Zudonu et al. (2024) who found positive effects on students' performance in Chemistry using AI in learning Chemistry.

Finding also shows that no significant difference exists in the academic performance scores of male and female students exposed to ChatGPT + IBS. This indicates that both male and female students benefited equally from the ChatGPT + IBS in learning Chemical Reaction and Equilibrium concepts. The absence of gender difference suggests that ChatGPT + IBS offers equal opportunities for academic success regardless of gender. This finding is consistent with the findings of Tijani (2025), Ojelade et al. (2024), Odukwe and Nwafor (2021), Yeboah and Siaw (2020), who revealed that there was no significant difference in the performance of male and female students exposed to IBS during and after treatment. Similarly, Ojelade (2024) found no gender differences in Chemistry achievement among students exposed in IBS. Moreover, Aregbesola et al. (2025) carried out a study to examine the impact of AI-Class-Point on the academic achievement of secondary school students in Chemistry and found no gender bias in the use of AI in learning Chemistry. However, the study findings, contradicts the findings of Sylvanus and Eke (2017), who observed that male students performed significantly better than female students in learning Chemistry when exposed to IBS.

6 Conclusions

Based on the findings of this study, it is concluded that both the ChatGPT + IBS and the conventional teaching method enhanced students' academic performance in Chemistry, while the ChatGPT + IBS was found to be gender-friendly, benefiting both male and female Senior Secondary School II students. However, these conclusions should be interpreted in light of the study limitations, including its restriction to only two secondary schools, the use of intact classes instead of random assignment, and the employment of a research assistant to teach the control group, which may have introduced bias and limited the generalizability of the findings.

7 Declarations

Conflict of Interest: The authors declare that there is no conflict of interest

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors

Authors Contributions: Author 1: Conceptualization, methodology, investigation, data collection. Author 2: Formal analysis, data curation, methodology, writing original draft preparation. Author 3: Data analysis, writing review and editing, and supervision. Author 4: Writing review, editing, and supervision. Both authors read and approved the final version of the manuscript.

Data Availability Statement: The data supporting the findings of this study are available from the corresponding author upon reasonable request

8 Reference

- Agu, N. N., & Okafor, C. C. (2021). Relationship between students' grades in WAEC and NECO Chemistry examination in Anambra State. *International Journal of Research and Innovation in Social Science*, 5(7), 90–94.
- Akhtar, N., Yasmeen, M., & Dar, M. U. (2025). Investigates the impact of integrating artificial intelligence (AI) in teaching chemistry at higher secondary school level. *Advances and Issues in Social Sciences (AISS)*, 1(1), 20. <https://aiss.pk>
- Aregbesola, B. G., Ojelade, I. A., & Samuel, S. B. (2025). Impact of artificial intelligence class point on the academic achievement of secondary school students in chemistry. *Cognify: Journal of Artificial Intelligence and Cognitive Science*, 2(1), 1–11.
- Awodun, A. O., Famuwagun, S. T., & Ayomide, A. J. (2024). Improving senior secondary school students' performance in chemistry through laboratory-based teaching strategy. *International Journal of Educational Research*, 7(9), 45–53. <https://ijojournals.com/index.php/er/article/view/933>
- Bruner, J. S. (1961). *The act of discovery*. Harvard Educational Review, 31(1), 21–32.
- Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). *The BSCS 5E instructional model: Origins and effectiveness*. BSCS.
- Chikendu, R. E., Obikezie, M.C., & Abumchukwu, A.A. (2021). Challenge of effective teaching of chemistry in the secondary schools in Enugu State. *International Journal of Research*, 8(10), 106- 117.
- Danjuma, J. P., & Mankilik, M. (2022). Effects of inquiry teaching strategy on senior secondary school students' retention and achievement in chemistry in Jalingo. *BW Academic Journal*, 1(1), 10. <https://www.bwjournals.org/index.php/bsjournal/article/view/623>
- Dauda, K., & Shoge, M. O. (2024). Perception of students toward learning chemistry in senior secondary school: A case study of Kaduna South. *International Journal of Research and Innovation in Social Science*, 8(3), 1919–1923.
- Ejilibe, O. C., Nnamonu, E. I., Chukwuemeka, P. C., Ifeanyi, J. C., Onyishi, S. O., & Onyeidu, B. U. (2020). Evaluation of gender difference influence: Effects of games on acquisition of science process skills in junior secondary school, South East Nigeria. *Journal of Education and Practice*, 11(15), 49–56. <https://doi.org/10.7176/JEP/11-15-06>
- Erno, P. L., II, & Berry, E. B. (2025). Impact of an AI-driven teacher dashboard on student performance in inquiry-based science learning. *International Journal of Science and Research Archive*, 15(2), 135–138. <https://doi.org/10.30574/ijstra.2025.15.2.1279>
- Global Education Monitoring Report Team. (2022). Global education monitoring report 2022: Gender report, Deepening the debate on those still left behind. UNESCO. <https://doi.org/10.54676/RCZB6329>
- Hong, J., Zhang, Y., & Zheng, X. (2022). Generative AI and the future of learning: Exploring potentials and pitfalls. *Computers in Human Behavior Reports*, 7, 100234. <https://doi.org/10.1016/j.chbr.2022.100234>
- Kaplan, A., & Haenlein, M. (2019). Siri, Siri, in my hand: Who's the fairest in the land? On the interpretations, illustrations, and implications of artificial intelligence. *Business Horizons*, 62(1), 15–25. <https://doi.org/10.1016/j.bushor.2018.08.004>
- Kotsis, K. T. (2024). Integrating ChatGPT into the inquiry-based science curriculum for primary education. *European Journal of Education and Pedagogy*, 5(6), 235–240.
- Krishna, L. S., Prasad, J. C., & Anjali, S. (2024). The impact of artificial intelligence in reshaping education: An analysis based on learning theories. ITM Web of Conferences, 68, 01008.
- Lucci, A., Santoro, F., & Rossi, G. (2022). The expanding frontier of generative AI: Emerging technologies and their societal impact. *AI & Society*, 37(3), 1039–1055. <https://doi.org/10.1007/s00146-021-01237-5>

- Nneka, O. F., & Otarigho, M. D. (2024). Artificial intelligence and chemistry learning outcomes of senior secondary school students in Warri Metropolis. *International Journal of Academic Pedagogical Research (IJAPR)*, 8(7), 7–14.
- Ntibi, J. E., & Neji, H. A. (2021). Effect of inquiry and concept mapping strategies on students' academic achievement in chemistry in Cross River State, Nigeria. *International Journal of Contemporary Social Science Education*, 2(1), 45–53.
- Odukwe, O. C., & Nwafor, S. C. (2021). Effect of guided-inquiry method on senior secondary school chemistry students' academic achievement in Anambra State, Nigeria. *Unizik Journal of Educational Research and Policy Studies*, 11(1). <https://sjifactor.com/passport.php?id=21363>
- Ojelade, I. A., Dajal, R. G., & Badamasi, M. F. (2024). Effect of inquiry teaching strategy on students' achievement in chemistry in senior secondary schools in Federal Capital Territory, Abuja. *Journal of Institutional Research, Big Data Analytics and Innovation*, 1(1), 1–31.
- Oladejo, A. I. (2022). Concept difficulty in secondary school chemistry: An intra-play of gender, school location, and school type. *Journal of Technology and Science Education*, 12(2), 190–202. <https://doi.org/10.3926/jotse.1902>
- Oyiza, I. N., Justice, O. I., Oguguo, B. C. E., Hannah, D. C., Chikwado, O. A., Ibrahim, Y., Izuchukwu, O. D., & Ndubumma, C. J. (2025). The role of artificial intelligence in enhancing chemistry education: A pathway to improve students' performance and academic achievement in Nsukka Education Zone. *International Journal of Research and Innovation in Social Science (IJRISS)*, 9(6), 1-27 <https://doi.org/10.47772/IJRISS.2025.906000384>
- Raman, Y., Surif, J., & Ibrahim, N. H. (2024). The effect of problem-based learning approach in enhancing problem-solving skills in chemistry education: A systematic review. *International Journal of Interactive Mobile Technologies (iJIM)*, 18(5), 126-143 <https://doi.org/10.3991/ijim.v18i05.47929>
- Russell, S. J., & Norvig, P. (2016). *Artificial intelligence: A modern approach (3rd ed.)*. Pearson.
- Selvarasu, S. (2023). The excellence of chemical science in achieving a sustainable world. *RSC Sustainability*, 1(7), 1604-1607
- Sweller, J. (2023). The development of cognitive load theory: Replication crises and incorporation of other theories can lead to theory expansion. *Educational Psychology Review*, 35(4), 95. <https://doi.org/>
- Sylvanus, T., & Eke, S. (2017). Effect of inquiry teaching strategy on academic achievement of senior secondary school chemistry students in Okrika Local Government Area. *International Journal of Education and Evaluation*, 3(12). Retrieved from www.iiardpub.org
- Taber, K. S. (2024). Educational constructivism. *Encyclopedia*, 4(4), 1534–1552.
- Tang, C., & Cooper, D. (2024). Generative artificial intelligence in education: A new paradigm for learning and assessment. *Educational Technology Research and Development*, 72(2), 445–462. <https://doi.org/10.1007/s11423-024-10234-6>
- Tijani, B. E. (2025). Impact of open inquiry instructional strategy on secondary school students' academic achievement and conceptual knowledge in chemistry across genders in Osun State, Nigeria. *A Journal of Spread Corporation*, 14(1), 120–141. ISSN 1916-7822.
- Umahaba, E. R. (2016). *Impact of 5E's Learning Model on Questioning Styles Preference and Academic Performance among Secondary School II Chemistry Students, Katisna Metropolis, Nigeria* [Unpublished Master's Dissertation]. Ahmadu Bello University, Zaria, Nigeria <http://kubanni.abu.ng/handle/123456789/8514>
- Yeboah, A., & Siaw, W. N. (2020). The impact of inquiry-based method of teaching on the academic performance of primary education students of Atebubu College of Education in general chemistry. *European Journal of Basic and Applied Sciences*, 7(1), 1–12.
- Zakariya, Y. F. (2025, January 21–28). *Teaching Generation Z students for productive learning: Introducing inquiry-driven collaborative learning model*. In *Proceedings of the 9th International Conference on Global Practice of Multidisciplinary Scientific Studies*, Havana, Cuba.

- Zhang, L., & Li, H. (2024). Integrating artificial intelligence into inquiry-based learning: Implications for student-centered education. *Computers & Education*, 205, 104962. <https://doi.org/10.1016/j.compedu.2024.104962>
- Zudonu, C., Eze, U., & Nwosu, P. (2024). Artificial intelligence in Chemistry education: Impacts on achievement and conceptual change. *International Journal of STEM Education*, 11(1), 88–101. <https://doi.org/10.1186/s40594-024-00488-2>

Publisher's Note

The views, interpretations, and conclusions expressed in this article are solely those of the author(s) and do not necessarily reflect the views or policies of the Journal of Studies in Science and Mathematics Education (JOSSME), its publisher, editorial board, editors, reviewers, or the authors' affiliated institutions. The publisher remains neutral with respect to jurisdictional claims in published maps, institutional affiliations, and other representations. Any products, materials, methods, or manufacturers mentioned or evaluated in this article are presented solely for scholarly purposes and do not constitute endorsement, recommendation, or guarantee by the publisher.