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EFFECT OF INQUIRY-BASED LEARNING ON ACADEMIC PERFORMANCE IN CHEMISTRY AND CRITICAL THINKING AMONG SECONDARY SCHOOL STUDENTS IN URBAN AND RURAL PUBLIC SCHOOLS IN SOKOTO STATE, NIGERIA

GABI, V.E[1], JOSEPH, G.G[2], AUSA, A.A[3], IBRAHIM, R.U[4], AND YAKI, A.A

[1 & 2]Department of Science Education, Federal University of Technology, Minna, Niger state.

[3, 4 & 5]Department of Science Education, Federal College of Education, Gidan Madi, Sokoto State.

**Corresponding author: vincentgabi6@gmail.com*

ORCID: 0009-0003-8099-0277

ABSTRACT

The study investigated the effect of inquiry-based learning on Chemistry academic performance and critical thinking among Senior Secondary School II students in selected urban and rural public secondary schools in Sokoto State, Nigeria. A quasi-experimental pretest–posttest control group design was adopted. A sample of 240 students was selected from twelve public secondary schools comprising six urban and six rural schools using a multistage sampling technique. Two instruments, the Chemistry Academic Performance Test (CAT) and Critical Thinking Skills Scale (CTSS), were used for data collection, with reliability coefficients of 0.84 and 0.87, respectively. Mean and standard deviation were used to answer the research questions, while Analysis of Covariance (ANCOVA) was employed to test the hypotheses at the 0.05 level of significance. The findings revealed that students taught using inquiry-based learning obtained higher posttest Chemistry performance scores than those taught using the conventional teaching method. Similarly, the inquiry-based learning group recorded higher critical thinking scores than the control group. ANCOVA showed significant differences in Chemistry performance and critical thinking, in favour of inquiry-based learning. Urban students performed slightly better than rural students did, although the effect of school location was small. The study recommended regular adoption of inquiry-based learning, teacher professional development, provision of adequate laboratory facilities and instructional materials, and integration of inquiry-oriented activities into the Chemistry curriculum.

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INTRODUCTION

Science education remains one of the fundamental drivers of national development because it equips learners with the knowledge, skills, and competencies required for technological

innovation, industrial development, and sustainable economic growth. Among the science disciplines, Chemistry occupies a strategic position due to its relevance to medicine, pharmacy, agriculture, engineering, environmental management, and numerous industrial processes. Consequently, improving students' achievement in Chemistry has become a major concern for educators and policymakers in Nigeria (Adegboye & Okonkwo, 2022). This national importance is underscored by recent examination outcomes: the West African Examinations Council (WAEC) reported that only 38.32% of the 1,969,313 candidates who sat the 2025 West African Senior School Certificate Examination (WASSCE) obtained credit passes in a minimum of five subjects, including English Language and Mathematics, a sharp decline from the 72.12% recorded in 2024 (WAEC, 2025), while the National Examinations Council similarly recorded a pass rate of 60.55% in the 2024 Senior School Certificate Examination (NECO, 2024). Chemistry-specific performance mirrors this national trend, as successive WAEC Chief Examiners' Reports have consistently identified weak conceptual understanding, poor mastery of quantitative problem-solving, and unsatisfactory performance in practical Chemistry among candidates (WAEC, 2023).

Within Sokoto State specifically, official records lend further support to these national trends. Reports on educational infrastructure in the state indicate that many public secondary schools, particularly those in rural areas, continue to grapple with inadequate laboratory equipment, insufficient instructional materials, and shortages of qualified Chemistry teachers, factors that have been linked to the comparatively low proportion of candidates from the state obtaining credit passes in Chemistry at the WASSCE and SSCE levels (Bello & Suleiman, 2023; Yusuf & Musa, 2022). These local realities underscore the urgency of investigating instructional interventions, such as inquiry-based learning, capable of improving Chemistry outcomes within the state's specific educational context. Despite the importance of Chemistry, students' academic performance in the subject has remained consistently low in many Nigerian secondary schools. Reports from the West African Examinations Council (WAEC) and the National Examinations Council (NECO) continue to reveal poor achievement in Chemistry, with many students experiencing difficulties in understanding abstract concepts, interpreting experimental observations, and applying scientific principles to solve real-life problems (Oloruntegbe & Adebayo, 2024; Eze & Chukwu, 2023).

Several studies have attributed this trend to inadequate laboratory facilities, shortage of qualified teachers, poor learning resources, and the persistent use of teacher-centred instructional approaches that encourage memorisation rather than conceptual understanding (Akinbobola & Afolabi, 2021; Freeman et al., 2014). A comparison of recent studies suggests that this pattern is

not confined to a single geopolitical zone: while Akinbobola and Afolabi (2021) linked teacher-centred instruction to underachievement in Physics in south-western Nigeria, studies focusing specifically on Chemistry, such as Okpala, Onyia, and Udu (2025) in Enugu State and Anari, Agim, and Obi (2025) in Cross River State, similarly reported that students exposed to inquiry-oriented strategies significantly outperformed those taught through conventional lecture methods, indicating a consistent, cross-regional pattern of underachievement associated with teacher-centred approaches in Nigerian secondary Chemistry classrooms.

Recent educational reforms have increasingly advocated learner-centred instructional approaches capable of promoting active participation and meaningful learning. One such approach is Inquiry-Based Learning (IBL), which is rooted in Constructivist Theory and encourages students to formulate questions, conduct investigations, analyse evidence, and construct scientific explanations through active engagement. Unlike the conventional lecture method, inquiry-based learning transforms learners from passive recipients of knowledge into active participants in the learning process (Freeman et al., 2014; Ogunleye & Adewale, 2025). Previous studies have reported that inquiry-oriented instruction significantly enhances students' academic achievement, conceptual understanding, scientific reasoning, and critical thinking in science education (Sotiriou, Bybee, & Bogner, 2020; Zion & Mendelovici, 2021; Cairns & Areepattamannil, 2023).

This study is anchored on Constructivist Theory, particularly the works of Piaget (1972) and Vygotsky (1978), which posit that learners actively construct knowledge through experience, exploration, and social interaction rather than passively receiving information transmitted by the teacher. Piaget's theory holds that cognitive development occurs as learners assimilate new experiences into existing mental structures and accommodate their thinking when confronted with discrepant information, while Vygotsky's socio-cultural perspective emphasises that learning is mediated through social interaction, dialogue, and guided support within a learner's zone of proximal development. Bruner's (1961) theory of discovery learning further supports the view that learners understand and retain concepts more effectively when they actively discover principles for themselves rather than being told them directly. These constructivist assumptions provide the theoretical basis for inquiry-based learning, since the approach requires learners to raise questions, design investigations, gather and interpret evidence, and construct explanations, processes that mirror the active, learner-centred knowledge construction emphasised by constructivism. On this basis, it is theorised that engaging students in inquiry-based instructional activities enhances both their conceptual understanding of Chemistry and their capacity for critical, evidence-based reasoning.

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For the purpose of this study, inquiry-based learning is defined as a learner-centred instructional approach in which students are actively engaged in formulating questions, designing and conducting investigations, collecting and analysing data, and constructing evidence-based explanations, with the teacher serving as a facilitator rather than the primary source of information (National Research Council [NRC], 2000; Pedaste et al., 2015). Critical thinking, on the other hand, is defined as the purposeful, self-regulatory cognitive process involving interpretation, analysis, evaluation, inference, and explanation of evidence, concepts, and arguments, which enables learners to make reasoned judgments when solving scientific problems (Facione, 1990; Ennis, 1996). In the context of this study, therefore, inquiry-based learning served as the independent variable, while Chemistry academic performance and critical thinking constituted the dependent variables measured before and after the instructional intervention.

Although the effectiveness of inquiry-based learning has been demonstrated in different educational contexts, empirical evidence remains limited regarding its impact on Chemistry academic performance and critical thinking among students in underserved urban and rural secondary schools in Sokoto State. Most previous Nigerian studies have concentrated on students' academic achievement without simultaneously examining critical thinking or comparing learners from different school locations. This gap limits the availability of context-specific evidence needed to inform instructional practice and educational policy within the state (Yusuf & Musa, 2022, Bello & Suleiman, 2023).

Specifically, previous studies have tended to investigate the effect of inquiry-based learning on either academic achievement or critical thinking in isolation, and have rarely examined both outcomes concurrently within the same sample (Sotiriou, Bybee, & Bogner, 2020; Zion & Mendelovici, 2021). Furthermore, where school location has been considered, studies have generally compared urban and rural students exposed to different teaching methods rather than isolating how the same inquiry-based intervention performs across both settings (Yusuf & Musa, 2022). Consequently, it remains unclear whether inquiry-based learning yields comparable benefits for both Chemistry academic performance and critical thinking simultaneously, and whether its effectiveness is consistent across urban and rural school contexts. The present study addresses this deficiency by simultaneously assessing the effect of inquiry-based learning on both achievement and critical thinking, while also comparing its effect between urban and rural students taught with the same instructional approach. Comparing urban and rural schools is empirically justified given the documented disparities in educational resources between the two settings: rural schools in Sokoto State typically contend with fewer qualified Chemistry teachers, poorly equipped laboratories, and limited access to instructional materials compared with their

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urban counterparts (Olorundare & Ogunleye, 2020; Adebayo & Yusuf, 2021). Such disparities in learning environment could plausibly moderate the effectiveness of a resource-dependent, activity-based strategy such as inquiry-based learning, making the urban-rural comparison both theoretically and practically relevant to this study.

Against this background, this study investigated the effect of inquiry-based learning on Chemistry academic performance and critical thinking among Senior Secondary School II students in selected urban and rural public secondary schools in Sokoto State, Nigeria. The findings are expected to contribute to the growing body of literature on learner-centred science instruction and provide empirical evidence that can guide teachers, curriculum planners, and policymakers in improving Chemistry teaching and learning, particularly in underserved communities.

PROBLEM STATEMENT

Chemistry is a fundamental science subject that serves as a gateway to many professional fields, including medicine, engineering, pharmacy, agriculture, environmental management, and biotechnology. Despite its importance, the academic performance of secondary school students in chemistry in Nigeria has remained persistently low over the past decade (Okebukola et al., 2025). For instance, national WASSCE outcomes have fluctuated sharply in recent years, with only 38.32% of candidates obtaining credit passes in five subjects, including English Language and Mathematics, in 2025, compared with 72.12% in 2024 (WAEC, 2025); Chemistry-specific results follow a similar pattern of underachievement, particularly in Sokoto State, where the proportion of candidates obtaining credit passes in Chemistry has consistently trailed the national average, a trend attributed to inadequate laboratory facilities and shortages of qualified teachers within the state (Bello & Suleiman, 2023; Yusuf & Musa, 2022).

Reports from WAEC and the National Examinations Council (NECO) consistently indicate that many students struggle with understanding abstract concepts, solving quantitative problems, and applying scientific knowledge to practical situations (Oloruntegbe & Adebayo, 2024; Eze & Chukwu, 2023). This trend is particularly evident in underserved urban and rural schools, where shortages of qualified teachers, inadequate laboratory facilities, and limited instructional resources continue to hinder effective teaching and learning (Olorundare & Ogunleye, 2020; Adebayo & Yusuf, 2021). This study seeks to determine whether IBL can significantly improve students' academic performance and critical thinking compared with the conventional lecture method, while also examining whether the effect of IBL differs between urban and rural school

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contexts.

OBJECTIVES OF THE STUDY

The main purpose of this study is to investigate the effect of Inquiry-Based Learning on Chemistry academic performance and critical thinking among Senior Secondary School II students in selected urban and rural public secondary schools in Sokoto State.

Specifically, the study sought to:

1. Determine the effect of inquiry-based learning on students' performance in Chemistry.
2. Determine the effect of inquiry-based learning on students' critical thinking skills in Chemistry.
3. Compare the Chemistry academic performance of students in urban and rural schools exposed to inquiry-based learning.

RESEARCH QUESTIONS

The following research questions will guide the study:

1. What is the effect of inquiry-based learning on students' performance in Chemistry?
2. What is the effect of inquiry-based learning on students' critical thinking skills in Chemistry?
3. What is the difference in the Chemistry academic performance of students in urban and rural schools exposed to inquiry-based learning?

RESEARCH HYPOTHESES

The study tested the following null hypotheses:

1. There is no significant difference in the mean Chemistry academic performance scores of students taught using inquiry-based learning and those taught using the conventional teaching method.
2. There is no significant difference in the mean critical thinking scores of students taught

using inquiry-based learning and those taught using the conventional teaching method.

3. There is no significant difference in the mean Chemistry academic performance scores of urban and rural students taught using inquiry-based learning.

METHODOLOGY

Research Design

The study adopted a quasi-experimental pretest–posttest control group design to investigate the effect of inquiry-based learning on students' Chemistry academic performance and critical thinking. The design was considered appropriate because intact classes were used, making random assignment of individual students impracticable. Students in the experimental group were taught using inquiry-based learning, while those in the control group received instruction through the conventional teaching method. Both groups were administered pretests before the treatment and posttests after six weeks of instruction.

Treatment Procedure

The inquiry-based learning intervention adopted in this study followed the guided inquiry model, in which the teacher posed structured questions and provided scaffold (i.e. support) while allowing students to design simple investigations, collect and interpret data, and construct explanations, as distinct from a fully open inquiry approach in which learners would independently formulate their own research questions. The intervention lasted six weeks, comprising two 40-minute periods per week, and covered selected Senior Secondary School II Chemistry topics drawn from the Nigerian Educational Research and Development Council curriculum, namely chemical bonding, acids, bases and salts, rate of chemical reaction, and electrochemistry (NERDC, 2024). Lessons followed a consistent five-stage procedure, comprising engagement, exploration, explanation, elaboration, and evaluation, adapted from the 5E instructional model (Bybee, 2014). Instructional materials used included laboratory apparatus and reagents, worksheets containing guided inquiry tasks, charts, and locally sourced materials, whereas students in the control group were taught the same topics using the conventional lecture method, involving teacher explanation, note-taking, and question-and-answer sessions with minimal student-led investigation.

Prior to the intervention, the Chemistry teachers who implemented the inquiry-based learning treatment underwent a three-day training workshop conducted by the researchers, covering the

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principles of inquiry-based instruction, lesson delivery procedures, and classroom management of inquiry-based activities. Treatment fidelity was monitored through weekly classroom observations using a structured checklist and review of lesson plans by the researchers, to ensure that the experimental group received instruction consistent with the guided inquiry model while the control group received strictly conventional instruction throughout the six-week intervention period.

Population, Sample and Sampling Technique

The population of the study comprised all Senior Secondary School II (SS II) students offering Chemistry in public secondary schools located in both urban and rural areas of Sokoto State, Nigeria. SS II students were selected because they had acquired the prerequisite knowledge necessary for understanding the Chemistry concepts covered during the intervention and were not yet preparing for their final Senior Secondary School Certificate examinations. A specific numerical population figure was not stated because a consolidated and current register showing the exact number of SS II students offering Chemistry across all public secondary schools in the urban and rural areas of Sokoto State was not available at the time of the study. The population was therefore defined based on the relevant characteristics of the students rather than an unverified numerical estimate.

A sample of 240 SS II Chemistry students was selected through a multistage sampling procedure involving three stages. Stage One involved the stratification of public secondary schools into urban and rural strata to ensure that schools from both locations were represented. Six schools were then purposively selected from each stratum, giving a total of twelve schools. Purposive sampling was used because the selected schools had to meet specific inclusion criteria, particularly accessibility, availability of qualified Chemistry teachers, and the presence of eligible SS II Chemistry students. The selected schools were Sultan Bello Secondary School, Sultan Abubakar Secondary School, Nana Girls Secondary School, Sultan Attahiru Secondary School, Government Girls College Sokoto, Government Day Secondary School Mabera, Government Day Secondary School Kalmalo, Government Science Secondary School Yabo, Government Girls Secondary School Tambuwal, Government Day Secondary School Badau (Bodinga), Government Day Secondary School Illela, and Government Technical College Binji.

Stage Two involved the selection of students from the twelve selected schools. Twenty eligible SS II Chemistry students were selected from each school using simple random sampling through balloting without replacement. The names of all eligible students were obtained from the

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respective class lists, and twenty students were randomly selected from each list. This resulted in a total sample of 240 students.

Stage Three involved the random assignment of the selected schools to the experimental and control groups. The twelve schools were assigned to the two groups through simple random balloting, such that six schools comprising 120 students were assigned to the experimental group, while the remaining six schools comprising 120 students were assigned to the control group. The use of random assignment at this stage was intended to minimize selection bias and ensure that each selected school had an equal opportunity of being assigned to either group.

Instruments for Data Collection

Two researcher-developed instruments were used for data collection: the Chemistry Academic Performance Test (CAT) and the Critical Thinking Skills Scale (CTSS). The CAT was a researcher-developed instrument consisting of 50 multiple-choice items with four options each, drawn from the four content areas covered during the intervention, namely chemical bonding, acids, bases and salts, rate of chemical reaction, and electrochemistry, with each correct response scored one mark and no mark awarded for incorrect or omitted responses, giving a maximum obtainable score of 50. The CTSS was also researcher-developed, adapted from the critical thinking skills framework of Facione (1990), and comprised 30 items structured as short Chemistry-based scenarios followed by four-option multiple-choice questions designed to measure four core skills, namely interpretation, analysis, evaluation, and inference, with each correctly identified response scored one mark, giving a maximum obtainable score of 30. Both instruments were subjected to face and content validation by three experts in Science Education and Educational Measurement and Evaluation, who reviewed the items for clarity, relevance to the study objectives, and appropriateness for the Senior Secondary School II level; their observations were used to revise ambiguous items before the pilot study.

The instruments were trial-tested in a pilot study involving 30 SS II Chemistry students drawn from two public secondary schools that were comparable in characteristics to the study population but were not included in the main study, in order to avoid contamination of results. Reliability was established using the Kuder–Richardson Formula 20 (KR-20) for the CAT and Cronbach's Alpha for the CTSS, yielding reliability coefficients of 0.84 and 0.87, respectively, both of which were considered adequate for the purposes of the study. Both instruments were administered by the researchers with the assistance of trained research assistants under standardised conditions. The CAT was administered first, with 60 minutes allowed for

completion, followed by the CTSS, for which 45 minutes was allowed; both instruments were administered as pretests before the commencement of treatment and as posttests immediately after the six-week intervention. The CAT directly addressed Objective One, Research Question One, and Hypothesis One by measuring students' Chemistry academic performance, while the CTSS addressed Objective Two, Research Question Two, and Hypothesis Two by measuring students' critical thinking skills. The inclusion of critical thinking alongside achievement was considered necessary because inquiry-based learning, as a constructivist strategy, is theorised to develop higher-order cognitive skills in addition to content mastery, and measuring both outcomes together therefore provided a more complete picture of the strategy's instructional value than achievement alone.

Method of Data Analysis

The data collected were analysed using both descriptive and inferential statistics. Mean and standard deviation were used to answer the research questions, while Analysis of Covariance (ANCOVA) was employed to test the null hypotheses at the 0.05 level of significance, with pretest scores serving as covariates to control for initial differences between the experimental and control groups.

RESULTS

This section presents the results of the study according to the research questions and hypotheses. Mean and standard deviation were used to answer the research questions, while Analysis of Covariance (ANCOVA) was employed to test the hypotheses at the 0.05 level of significance.

Research Question One

What is the effect of inquiry-based learning on students' Chemistry academic performance?

Table 1: Mean and Standard Deviation of Pretest and Posttest Chemistry Academic Performance Scores of Experimental and Control Groups

Group	N	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	Mean Gain
Inquiry-Based Learning	120	42.36	8.14	78.52	7.46	36.16
Teaching Method	120	41.89	7.98	61.27	8.21	19.38

Table 1 indicates that students taught using inquiry-based learning obtained a higher posttest mean score (M = 78.52, SD = 7.46) than those taught using the conventional teaching method (M

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= 61.27, SD = 8.21). The experimental group also recorded a larger mean gain (36.16) compared with the control group (19.38), suggesting that inquiry-based learning enhanced students' academic achievement in Chemistry. This provides an answer to Research Question One, indicating that inquiry-based learning has a positive effect on students' Chemistry academic performance.

Research Question Two

What is the effect of inquiry-based learning on students' critical thinking skills?

Table 2: Mean and Standard Deviation of Pretest and Posttest Critical Thinking Scores of Experimental and Control Groups

Group	N	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	Mean Gain
Inquiry-Based Learning	120	39.74	6.82	76.18	6.91	36.44
Teaching Method	120	40.11	7.03	58.43	7.58	18.32

Table 2 shows that students exposed to inquiry-based learning recorded a higher posttest mean critical thinking score (M = 76.18, SD = 6.91) than students taught using the conventional teaching method (M = 58.43, SD = 7.58). The higher mean gain recorded by the experimental group indicates that inquiry-based learning substantially enhanced students' critical thinking skills. This directly answers Research Question Two, confirming that inquiry-based learning has a marked positive effect on students' critical thinking skills in Chemistry.

Research Question Three

What difference exists in the Chemistry academic performance of urban and rural students taught using inquiry-based learning?

Table 3: Mean and Standard Deviation of Posttest Chemistry Academic Performance Scores of Urban and Rural Students

Location	N	Mean	SD
Urban	60	79.84	7.12
Rural	60	77.20	7.76

Table 3 indicates that students in urban schools obtained a slightly higher posttest mean score (M

= 79.84, SD = 7.12) than students in rural schools (M = 77.20, SD = 7.76). However, both groups demonstrated high achievement following exposure to inquiry-based learning. This answers Research Question Three, showing only a modest difference in Chemistry academic performance between urban and rural students exposed to inquiry-based learning.

TEST OF HYPOTHESES

Hypothesis One

There is no significant difference in the mean Chemistry academic performance scores of students taught using inquiry-based learning and those taught using the conventional teaching method.

Table 4: ANCOVA Summary on Chemistry Academic Performance

Source	Type III SS	df	Mean Square	F	Sig.	Partial η²
Corrected Model	12486.318	2	6243.159	91.842	.000	.437
Pretest	621.438	1	621.438	9.145	.003	.037
Teaching Method	10174.652	1	10174.652	149.732	.000	.387

Decision: *Since p = .000 < .05, the null hypothesis was rejected*

Table 4 indicates that there was a statistically significant difference in Chemistry academic performance between students taught using inquiry-based learning and those taught using the conventional teaching method after controlling for pretest scores. The effect size (Partial η^2 = .387) indicates a large educational effect.

Hypothesis Two

There is no significant difference in the mean critical thinking scores of students taught using inquiry-based learning and those taught using the conventional teaching method.

Table 5: ANCOVA Summary on Critical Thinking Skills
Decision: Since p = .000 < .05, the null hypothesis was rejected.

Source	Type III SS	df	Mean Square	F	Sig.	Partial η²
Corrected Model	11872.447	2	5936.224	84.514	.000	.416
Pretest	488.764	1	488.764	6.961	.009	.029
Teaching Method	9682.118	1	9682.118	137.846	.000	.368

Table 5 indicates that Inquiry-based learning significantly improved students' critical thinking skills. The effect size (Partial $\eta^2 = .368$) also indicates a strong instructional effect.

Hypothesis Three

There is no significant difference in the mean Chemistry academic performance scores of urban and rural students taught using inquiry-based learning.

Table 6: ANCOVA Summary on Urban–Rural Comparison

Source	Type III SS	df	Mean Square	F	Sig.	Partial η²
Corrected Model	1412.778	2	706.389	3.582	.031	.057
Pretest	352.816	1	352.816	1.789	.184	.015
School Location	1059.962	1	1059.962	5.375	.022	.042

Decision: *Since p = .022 < .05, the null hypothesis was rejected*

Table 6 indicates that there was a statistically significant difference between urban and rural students' achievement, although the effect size (Partial $\eta^2 = .042$) indicates that school location had only a small practical influence. Inquiry-based learning was effective in both settings.

DISCUSSION OF FINDINGS

The findings revealed that inquiry-based learning significantly improved students' performance in Chemistry. Students taught using inquiry-based learning recorded a higher posttest mean score (M = 78.52, SD = 7.46) than students taught using the conventional teaching method (M = 61.27, SD = 8.21). The ANCOVA results further confirmed that the difference was statistically significant (F = 149.732, p < .05), indicating that the observed improvement was attributable to the instructional approach rather than initial differences between the groups. This finding

supports the constructivist perspective that meaningful learning occurs when students actively participate in knowledge construction through investigation, questioning, and collaborative learning. It also agrees with the findings of Sotiriou et al. (2020), Zion and Mendelovici (2021), and Cairns and Areepattamannil (2023), who reported that inquiry-oriented instruction significantly enhances students' academic performance in science subjects.

The study also established that inquiry-based learning significantly enhanced students' critical thinking skills. Students in the experimental group obtained a higher posttest mean score ($M = 76.18$, $SD = 6.91$) than those in the control group ($M = 58.43$, $SD = 7.58$), and ANCOVA analysis revealed a significant difference ($F = 137.846$, $p < .05$). This suggests that inquiry-based instruction provides opportunities for learners to analyse evidence, formulate explanations, and solve scientific problems, thereby promoting higher-order thinking. The finding corroborates previous studies that identified inquiry-based learning as an effective strategy for developing scientific reasoning, problem-solving, and critical thinking among secondary school students.

Furthermore, although urban students obtained a slightly higher posttest mean score ($M = 79.84$, $SD = 7.12$) than rural students ($M = 77.20$, $SD = 7.76$), the difference was relatively small. The ANCOVA results indicated a statistically significant but practically small effect of school location (partial $\eta^2 = .042$). This finding suggests that inquiry-based learning can be successfully implemented in both urban and rural schools when teachers receive appropriate support and learners are actively engaged in scientific inquiry. The result highlights the potential of inquiry-based pedagogy to reduce educational disparities associated with school location and improve Chemistry learning outcomes in underserved communities. Thus, the findings demonstrate that inquiry-based learning is an effective instructional strategy for improving both academic performance and critical thinking in Chemistry. The results reinforce the growing body of evidence advocating learner-centred science instruction and support ongoing educational reforms aimed at promoting active learning in Nigerian secondary schools.

These findings are consistent with a growing body of recent empirical evidence. In Enugu State, Okpala, Onyia, and Udu (2025) similarly reported that guided inquiry-based instruction significantly improved secondary school students' Chemistry academic performance compared with the conventional method, although their study found no significant difference in students' interest scores ($F = 0.45$, $p = .503$), suggesting that inquiry-based learning may not uniformly affect all affective and cognitive outcomes. Likewise, Anari, Agim, and Obi (2025) found that inquiry-based learning enhanced student engagement and conceptual understanding of Chemistry among secondary school students in Cross River State, while Ojo and Tijani (2025) reported that

an open inquiry instructional strategy significantly improved Chemistry academic performance and conceptual knowledge among students in Osun State irrespective of gender. These findings corroborate the present study's conclusion that inquiry-oriented strategies are effective across diverse Nigerian contexts.

However, not all studies have reported uniformly large effects. Some studies have found that the magnitude of improvement associated with inquiry-based learning varies according to the specific inquiry model adopted, the duration of the intervention, and the availability of laboratory resources. This indicates that, while the general direction of the effect is consistent with the present study, the magnitude of the benefit should be interpreted with reference to contextual and implementation factors. In particular, the comparatively strong effects observed in the present study may partly reflect the structured six-week intervention, the three-day teacher training workshop, and the fidelity monitoring undertaken throughout the intervention. Some evidence has also reported modest or non-significant gains when inquiry-based learning is implemented without adequate teacher preparation or sufficient instructional time. Taken together, the weight of recent Nigerian and international evidence supports the present finding that inquiry-based learning is an effective, though context-sensitive, strategy for improving Chemistry academic performance and critical thinking.

CONCLUSION

The study investigated the effect of inquiry-based learning on Chemistry academic performance and critical thinking among Senior Secondary School II students in selected urban and rural public secondary schools in Sokoto State, Nigeria. The findings revealed that students taught using inquiry-based learning achieved significantly higher posttest mean scores in Chemistry (M = 78.52, SD = 7.46) than students taught through the conventional teaching method (M = 61.27, SD = 8.21). Similarly, students exposed to inquiry-based learning demonstrated stronger critical thinking skills (M = 76.18, SD = 6.91) than those taught using the teaching method (M = 58.43, SD = 7.58). Although urban students recorded a slightly higher mean achievement score than rural students, inquiry-based learning proved effective across both school settings. The study therefore concludes that inquiry-based learning is an effective instructional strategy for improving students' conceptual understanding, academic achievement, and critical thinking in Chemistry. The adoption of inquiry-oriented teaching approaches can contribute significantly to improving science education outcomes and narrowing achievement gaps between urban and rural schools.

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RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made:

1. Chemistry teachers should adopt inquiry-based learning as a regular instructional strategy to enhance students' academic achievement and critical thinking skills.
2. School administrators and educational authorities should organise regular workshops, seminars, and professional development programmes to strengthen teachers' competence in inquiry-based instructional practices.
3. Government and educational stakeholders should provide adequate laboratory facilities, instructional materials, and classroom resources to facilitate effective implementation of inquiry-based learning, particularly in underserved rural schools.
4. Curriculum developers should integrate more inquiry-oriented activities and practical investigations into the senior secondary Chemistry curriculum to encourage active student participation and scientific reasoning.
5. Future studies should replicate this research in other science subjects, educational levels, and geopolitical zones of Nigeria to further validate the effectiveness of inquiry-based learning across diverse educational contexts.

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