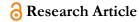
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# Effectiveness of Open Inquiry Instructional Strategy on Secondary School Chemistry Students' Conceptual Knowledge

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#### Abstract

Chemistry is a cornerstone of science, yet students in Nigeria often face challenges in achieving conceptual understanding due to the reliance on traditional teaching methods. These methods prioritise rote memorisation over deep comprehension, limiting students' ability to apply scientific principles effectively. To address this challenge, this study investigates the impact of the open inquiry instructional strategy in enhancing secondary school students' conceptual knowledge in chemistry. Using a quasi-experimental pre-test-posttest design, 322 Senior Secondary School 1 (SSS 1) students from six purposively selected schools participated in the study. The experimental group (166 students) was taught using open inquiry while the control group (156 students) received demonstration-based instruction. Data were collected using the Two-Tier Diagnostic Test (TTDT), assessing students' ability to explain concepts, make connections, and apply scientific reasoning. Paired samples t-tests and ANCOVA were employed for data analysis. The findings revealed that students taught with open inquiry demonstrated significantly higher conceptual knowledge than those taught with the demonstration method. Notably, no significant differences were observed in outcomes between public and private school students, indicating the strategy's adaptability across different educational contexts. These findings contribute to the growing body of knowledge on effective instructional strategies for teaching chemistry in senior secondary schools and highlight the importance of integrating open inquiry into science curricula. The study recommends the incorporation of inquiry-based teaching approaches alongside adequate teacher training to enhance students' learning experiences. Future research should explore the long-term impact of open inquiry and its effectiveness in other scientific disciplines.

Keywords: Conceptual Knowledge, Instructional Strategies, Open Inquiry, Student-Centred Approach

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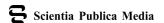


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# 1. INTRODUCTION

Chemistry is a core subject in the science curriculum, critical for understanding various scientific phenomena and for preparing students for careers in science, technology, engineering, and mathematics (STEM). However, numerous studies have highlighted persistent challenges in teaching and learning chemistry effectively at the secondary school level. Traditional lecture-based methods, which dominate many classrooms, often fail to engage students or develop their conceptual understanding and scientific process skills (Khasawneh, 2023). This problem is particularly acute in developing countries such as Nigeria, where educational resources are often limited, and pedagogical practices may not keep pace with contemporary educational research (Amadi & Nwogu, 2023)

The inadequacy of traditional teaching methods in fostering deep learning in chemistry is welldocumented. These methods typically emphasise rote memorisation of facts and formulas rather than understanding underlying concepts and principles (Annisa & Rohaeti, 2018). The limitations of teachercentred instructional methods, like the demonstration method, have sparked an increasing interest in student-centred approaches such as open inquiry, which highlights active participation, critical analysis, and



problem-solving by enabling students to autonomously investigate learning materials and utilise digital resources, including online videos, simulations, and virtual tools (Ojo & Tijani, 2025). As a result, students often struggle to apply their knowledge in novel situations, leading to poor performance in examinations and a lack of interest in pursuing further studies in chemistry and related fields. This disconnect between teaching practices and learning outcomes underscores the need for innovative instructional strategies that can enhance students' conceptual understanding. One promising approach is inquiry-based learning, which involves students actively engaging in the scientific process by posing questions, conducting experiments, and drawing conclusions based on their observations (Onyema et al., 2019). Within this framework, open inquiry represents the most student-centred form, where learners independently design and conduct investigations with minimal guidance from the teacher (Tsivitanidou & Rybska, 2018).

Conceptual knowledge, notably within the area of chemistry, represents a vital component of scientific literacy and education. Conceptual knowledge is a fundamental part of learning that relates to the comprehension of core principles and concepts within a subject area. It enables learners to link concepts, apply knowledge in multiple contexts, and participate in higher-order thinking. In chemistry, conceptual understanding is required for students to grasp fundamental chemical principles, such as atomic structure, chemical bonding, and reaction mechanisms. This comprehension goes beyond rote memorisation of data; it entails identifying the fundamental links and processes that regulate chemical phenomena (Okafor, 2021). The relevance of conceptual knowledge in promoting scientific literacy and problem-solving skills has led to greater interest in how it can be effectively tested and fostered within educational settings.

The indices of conceptual knowledge in chemistry can be identified by certain indicators that show a learner's level of comprehension. These include the ability to explain concepts clearly, make connections between different chemical ideas, apply knowledge to novel situations, and demonstrate scientific reasoning in problem-solving contexts (Kushta & Prenga, 2023). However, this study focused on three of these crucial indicators, especially the student's ability to explain concepts clearly, make connections between distinct chemical ideas, and display scientific reasoning in problem-solving scenarios. These factors are particularly helpful in assessing conceptual understanding in chemistry (Kushta & Prenga, 2023). Students with high conceptual knowledge in chemistry can articulate the principles underpinning chemical reactions at both macroscopic and molecular levels, predict the outcomes of experiments based on these principles, and design experiments to test their hypotheses. For instance, when examining a new chemical reaction, a student with deep conceptual understanding would not only be able to describe the observable changes but also explain the underlying molecular interactions, draw connections to similar reactions they have studied, and propose potential applications in different contexts.

Inquiry instructional strategies are highly effective in enhancing students' conceptual understanding of chemistry. This method allows students to explore scientific phenomena independently, encouraging them to construct and internalise knowledge. By engaging directly with concepts through experiments and problem-solving, students develop a deeper and more interconnected understanding of chemical principles (Owolade et al., 2022). Conceptual knowledge, which involves the comprehension of core principles and their interrelations, is critical in chemistry. Open inquiry facilitates this by promoting active learning and critical reflection. For instance, students investigating the behaviour of gases can develop a nuanced understanding of the gas laws by designing experiments and analysing results. This hands-on experience reinforces theoretical knowledge and helps students identify connections between different chemical concepts (Okafor, 2016).

Another benefit of open inquiry is its ability to address and correct misconceptions. By engaging in inquiry-based learning, students are encouraged to question their assumptions and refine their understanding based on evidence (Qashdi et al., 2022). This iterative process not only improves conceptual clarity but also fosters scientific reasoning, an essential skill in chemistry and other STEM fields. Open inquiry also supports the application of knowledge in novel contexts. Students are often required to transfer their understanding of chemical principles to solve unfamiliar problems, such as predicting the outcomes of new reactions or designing innovative experiments (Rahmawan et al., 2021). This ability to generalise and apply knowledge demonstrates a high level of conceptual mastery and prepares students for advanced studies in chemistry. The reflective nature of open inquiry further enhances conceptual understanding. As students analyse their findings and discuss their implications, they consolidate their knowledge and develop a holistic perspective of the subject (Kushta & Prenga, 2023). This reflection ensures that learning is meaningful and enduring, providing a strong foundation for future academic and professional pursuits.

The poor performance of Nigerian students in chemistry is evident in national examination results. Reports from the West African Examinations Council (WAEC) consistently indicate low pass rates in chemistry, with many students failing to achieve the required credits for tertiary education admission (WAEC, 2020). This trend is alarming, given the importance of chemistry in scientific literacy and its role in national development. The underachievement in chemistry can be attributed to several factors, including ineffective teaching methods, lack of adequate laboratory facilities, and insufficient teacher training in modern pedagogical techniques.

Moreover, the gap between public and private schools in Nigeria presents another layer of complexity. Public schools often face significant resource constraints, including inadequate funding, poor infrastructure, and high student-teacher ratios (Alao & Okoliko, 2024; Ogunode et al., 2024). In contrast, private schools generally have better resources and more favourable learning environments, though they may still struggle with outdated teaching practices. Investigating the effectiveness of open inquiry across both public and private schools can provide valuable insights into its potential to address educational disparities and improve overall student outcomes in chemistry.

The study aims to fill the gap in the literature by providing empirical evidence on the effectiveness of open inquiry instructional strategy in the Nigerian educational context. By comparing the outcomes of students exposed to open inquiry with those taught using traditional methods, this research seeks to determine whether open inquiry can enhance conceptual understanding in chemistry. Furthermore, by including both public and private schools in the study, the research will explore the potential of open inquiry to mitigate educational disparities and improve overall student outcomes.

### 1.1. Research Objectives

The main purpose of this study is to assess the impact of open inquiry instructional strategy on secondary school chemistry students' conceptual knowledge. The specific objectives of the study were to:

- 1. Assess the impact of open inquiry on the conceptual knowledge of senior secondary school students in chemistry.
- 2. Compare the difference in the conceptual knowledge of students taught using the demonstration instructional strategy and those taught using the open inquiry instructional strategy.
- 3. Compare the conceptual knowledge between public and private school students taught using the open inquiry instructional strategy

# 1.2. Research Questions

The study answered the following questions:

- 1. What is the impact of open inquiry on the conceptual knowledge of senior secondary school students in chemistry?
- 2. Is there any difference in the conceptual knowledge of students taught using the demonstration instructional strategy and those taught using the open inquiry instructional strategy?
- 3. What is the difference in the conceptual knowledge of public and private school students taught using open inquiry?

#### 2. METHODS

### 2.1. Research Design

The study adopted a non-equivalent quasi-experimental design with a pre-test-post-test control group format. This design was selected to evaluate the impact of open inquiry instructional strategy compared to the demonstration instructional strategy on students' conceptual knowledge in chemistry. The quasi-experimental approach allowed the researcher to work with intact classes, ensuring minimal disruption to the natural learning environment. To determine the appropriate sample size, a priori power analysis was conducted using G\*Power software. The analysis was based on the following parameters: a medium effect size (f) of 0.25, as recommended for educational interventions; a significance level ( $\alpha$ ) of 0.05, representing a 5% probability of committing a Type I error; and a power level (1 -  $\beta$ ) of 0.80, ensuring

an 80% chance of detecting a significant effect if one existed. Additionally, two groups (experimental and control) and two measurements (pretest and posttest) were considered in the computation. The analysis indicated a minimum required sample size of 128 participants (64 per group) to achieve sufficient statistical power. However, the study utilised a total sample size of 322 students, which represented all the students in the intact classes selected from six secondary schools. This larger sample size not only enhanced the statistical robustness of the findings but also ensured the inclusion of diverse student characteristics, further strengthening the generalisability of the results. By working with intact classes, the study minimised potential biases and ensured consistency in the instructional strategies applied during the intervention.

### 2.2. Population for the Study

The target population for the study consisted of Senior Secondary School 1 (SSS 1) students in Osun State, Nigeria while the accessible population comprised all Senior Secondary School 1 (SSS 1) chemistry students in Osun East Senatorial District. This population was chosen due to its diverse mix of public and private schools, enabling a comprehensive analysis of instructional strategies across varying educational contexts.

# 2.3. Sample and Sampling Techniques

A total of six schools were purposively selected to represent both public and private institutions within the district. The schools were purposively selected to ensure representation from those with a minimum enrolment of 50 students in their SSS 1 classes. Furthermore, a simple random sampling was chosen to divide the selected schools into two groups. This is done to ensure that all schools in the district have an equal chance of being picked, thereby minimising bias. In each school, one intact class was selected and assigned to either the experimental group (open inquiry instructional group) or the control group (demonstration instruction group). The resulting total sample was 322 students, consisting of 166 in the open inquiry group and 156 in the demonstration strategy group.

# 2.4. Research Instrument

The Two-Tier Diagnostic Test (TTDT) was used as the instrument for data collection. The TTDT was developed following the structure from the study of Hasanah et al. (2023) and Hutahaean et al. (2024) and modified by the researcher to evaluate students' conceptual knowledge in chemistry through their ability to explain concepts, make connections, and demonstrate scientific reasoning on three key topics in chemistry: the concepts of atoms molecules and ions, the concepts of elements, compounds and mixtures and separation techniques. The TTDT consists of three sections: Section A collects demographic data, including respondents' gender and school type; Section B contains ten first-tier questions that assess the clarity of explanation and the connections made between concepts; and Section C includes ten second-tier questions that evaluate the scientific reasoning behind the responses in the first-tier questions. This structure allows for a comprehensive assessment of both factual knowledge and the ability to articulate and reason through concepts. In the first tier, students are awarded 2 marks for a clear explanation with a strong connection and 1 mark for a clear explanation without connections. The second tier awards 1 mark for a correct demonstration of scientific reasoning, contingent on receiving full credit in the first tier. The maximum obtainable score on the TTDT is 30 marks, reflecting the importance of both tiers in understanding students' conceptual knowledge.

### 2.5. Validity and Reliability of TTDT

The Two-Tier Diagnostic Test (TTDT) employed in this study underwent rigorous validation to ensure its appropriateness for assessing students' conceptual knowledge in chemistry. Content validity was established through expert reviews by experienced chemistry educators and assessment specialists, who evaluated the test items for alignment with the intended learning objectives and their relevance to the study's constructs. Their feedback was used to refine the instrument, ensuring clarity, accuracy, and representativeness of the concepts assessed.

To determine the reliability of the instrument, inter-rater reliability was assessed using the Intraclass Correlation Coefficient (ICC), yielding a reliability coefficient of 0.821. This indicates a high level of agreement between the two independent raters, confirming the consistency of the scoring. Furthermore, internal consistency reliability was examined using Cronbach's alpha, which yielded a perfect value of 1.000 for both test parts. The correlation between test forms was 0.981, further demonstrating strong internal reliability. The Spearman-Brown coefficient values for both equal and unequal length conditions were 0.991, confirming the stability of the test scores. Additionally, the Guttman Split-Half coefficient was found to be 0.881, further reinforcing the instrument's reliability. These results collectively indicate that the TTDT is a highly reliable instrument for assessing students' conceptual understanding in chemistry.

#### 2.6. Procedure for Data Collection

The data collection process commenced with a pre-test administered to both the experimental and control groups using the Two-Tier Diagnostic Test (TTDT) to establish baseline conceptual knowledge. The intervention lasted six weeks, with the experimental group taught using the open inquiry instructional strategy, which emphasised student-driven exploration and minimal teacher guidance. The control group, in contrast, received instruction via the demonstration instructional strategy, focusing on teacher-led experiments and explanations. After the intervention, the TTDT was re-administered as a post-test to measure changes in conceptual knowledge.

### 2.7. Methods of Data Analysis

The study's data were analysed using the Statistical Package for Social Science (SPSS) version 27.0. The analysis began with a descriptive presentation, including the frequency and percentage of respondents' gender and school type. This is followed by analysing the impact of open inquiry on the students' conceptual knowledge using a paired sample statistic. Finally, data from the pretest and posttest were analysed using ANCOVA to control for initial differences and assess the impact of the instructional strategies.

# 3. RESULTS

### 3.1. Descriptive Presentation of Data

Table 1 presents the frequency and percentage distribution of respondents based on their school type. The majority of respondents, 270 students (83.9%), were from public schools, while 52 students (16.1%) were from private schools. This indicates that the sample is predominantly drawn from public schools, reflecting the broader representation of public secondary schools within the study area. The cumulative percentage shows that all respondents (100%) were accounted for across the two school types.

<b>Table 1.</b> Frequency and P	ercentage Distri	bution of Respondents'	School Type
	School T	ype	
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School Type						
		Frequency	Percent	Valid Percent	<b>Cumulative Percent</b>	
Valid	Public	270	83.9	83.9	83.9	
	Private	52	16.1	16.1	100.0	
	Total	322	100.0	100.0		

Table 2. Frequency and Percentage Distribution of Respondents' Gender

Gender							
		Frequency	Percent	Valid Percent	<b>Cumulative Percent</b>		
Valid	Male	147	45.7	45.7	45.7		
	Female	175	54.3	54.3	100.0		
	Total	322	100.0	100.0			

Table 2 presents the gender distribution of respondents. Out of the 322 participants, 147 (45.7%) were male, and 175 (54.3%) were female. This shows a slightly higher representation of female students in

the sample. The cumulative percentage confirms that the gender distribution is comprehensive, with all respondents accounted for, providing a balanced gender perspective in the study.

### 3.2. Analysis of Research Questions

**Research Question 1**: What is the impact of open inquiry on the conceptual knowledge of senior secondary school students in chemistry?

The descriptive statistics in Table 3 reveal the mean scores for the TTDT (Two-Tier Diagnostic Test) pre-test and post-test in the open inquiry group. The mean pre-test score was 12.59 (N = 322, SD = 5.835), while the mean post-test score increased to 16.39 (N = 322, SD = 6.682). This indicates a noticeable improvement in the conceptual knowledge of senior secondary school students in chemistry after being taught using the open inquiry instructional strategy. The higher mean in the post-test compared to the pre-test suggests that the open inquiry approach positively impacted students' conceptual knowledge, as evidenced by the difference in scores. The relatively small standard errors of the mean (0.325 for the pre-test and 0.372 for the post-test) indicate that the sample mean is a reliable estimate of the population mean.

Table 3. Descriptive Statistics of the Open Inquiry Group Scores in the TTDT

Paired Samples Statistics

Paired Samples Statistics							
		Mean	N	Std. Deviation	Std. Error Mean		
Pair 1	TTDT Pre-test Score	12.59	322	5.835	.325		
	TTDT Post-test Score	16.39	322	6.682	.372		

**Research Question 2**: Is there any difference in the conceptual knowledge of students taught using the demonstration instructional strategy and those taught using the open inquiry instructional strategy?

Table 4 presents the descriptive statistics for the post-test scores of students in the demonstration and open inquiry instructional strategy groups. The mean post-test score for students taught using the demonstration instructional strategy was 13.58 (SD = 4.85, n = 156), while the mean score for students in the open inquiry instructional strategy group was 19.02 (SD = 7.10, n = 166). The total mean score across both groups was 16.39 (SD = 6.68, N = 322). These results suggest that students taught using the open inquiry instructional strategy achieved higher post-test scores on the Two-Tier Diagnostic Test (TTDT) than those taught using the demonstration strategy.

**Table 4.** Descriptive Statistics Comparing the Difference in Conceptual Knowledge Between the Open Inquiry and Demonstration Groups

Dependent Variable: TTDT Post-test Score						
Instructional Strategies	Mean	Std. Deviation	N			
Demonstration	13.58	4.853	156			
Open Inquiry	19.02	7.095	166			
Total	16.39	6.682	322			

**Table 5.** ANCOVA Result Comparing the Differences in the Scores of Students in the Open Inquiry and Demonstration Groups

	Dependent Variable: TTDT Post-test Score						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	
Corrected Model	2507.518a	2	1253.759	33.823	.000	.175	
Intercept	12632.011	1	12632.011	340.778	.000	.517	
TTDT Pre-test	132.132	1	132.132	3.565	.060	.011	
Treatment	2325.536	1	2325.536	62.737	.000	.164	
Error	11824.731	319	37.068				
Total	100780.000	322					
Corrected Total	14332.248	321					

a. R Squared = .175 (Adjusted R Squared = .170)

An ANCOVA was conducted to determine whether the observed difference in students' conceptual knowledge, as measured by the TTDT post-test, was statistically significant after controlling for pre-test scores. Table 5 shows that the corrected model accounted for 17.5% of the variance ( $R^2 = .175$ , Adjusted  $R^2 = .170$ ) in students' post-test scores. The treatment effect (i.e., instructional strategy) was statistically significant, F(1, 319) = 62.737, p < .001,  $\eta^2 = .164$ , indicating a large effect size. This result suggests that the type of instructional strategy had a significant impact on students' conceptual knowledge. The pre-test scores were not a significant covariate, F(1, 319) = 3.565, p = .060,  $\eta^2 = .011$ , meaning students' initial conceptual knowledge did not significantly influence their post-test scores.

**Table 6.** Bonferroni Post-hoc Analysis of Students' Conceptual Knowledge in TTDT Based on Instructional Strategies

Treatment (I)	Treatment (J)	Mean Difference	Sig.b	95% Confidence Interval for Difference <sup>b</sup>	
, ,	-	(I-J)		Lower Bound	Upper Bound
Control	Open Inquiry	-5.382*	< 0.001	-6.719	-4.045
Open Inquiry	Control	5.382*	< 0.001	4.045	6.719

Based on estimated marginal means: \*. The mean difference is significant at the 0.05 level. b. Adjustment for multiple comparisons: Bonferroni.

To further examine the pairwise differences between instructional strategies, a Bonferroni post-hoc analysis was conducted (Table 6). The results indicate a statistically significant difference between the open inquiry and demonstration groups (Mean Difference = 5.382, p < .001). Students in the open inquiry group performed significantly better than those in the demonstration group, with a 95% confidence interval (4.045, 6.719). This confirms that the open inquiry instructional strategy enhanced students' conceptual knowledge more effectively than the demonstration strategy.

**Research Question 3:** What is the difference in the conceptual knowledge of public and private school students taught using open inquiry?

The descriptive statistics in Table 7 show the mean TTDT (Two-Tier Diagnostic Test) post-test scores for public and private school students taught using the open inquiry instructional strategy. Public school students achieved a mean score of 16.51 (N = 270, SD = 6.341), while private school students had a slightly lower mean score of 15.71 (N = 52, SD = 8.268). The overall mean post-test score across both groups was 16.39 (N = 322, SD = 6.682). This suggests a small difference in favour of public school students

**Table 7.** Descriptive Statistics Comparing the Difference in Conceptual Knowledge Between the Public and Private School Students in the Study Area

Dependent Variable: TTDT Post-test Score					
School Type	Mean	Std. Deviation	$\mathbf{N}$		
Public	16.51	6.341	270		
Private	15.71	8.268	52		
Total	16.39	6.682	322		

The ANCOVA results in Table 8 indicate that this difference is not statistically significant. The effect of school type on post-test scores was not significant (F(1, 319) = 0.485, p = .487, Partial Eta Squared = .002) after controlling for TTDT pre-test scores, suggesting that school type had no meaningful impact on students' conceptual knowledge when using the open inquiry strategy. The covariate (TTDT pre-test scores) was significant (F(1, 319) = 3.959, p = .047, Partial Eta Squared = .012), indicating that prior knowledge had a small but notable effect on post-test scores. The corrected model explained only 1.4% of the variance in post-test scores (Adjusted R Squared = 0.8%), highlighting that the differences in conceptual knowledge between public and private school students were minimal and largely independent of the instructional strategy employed.

Dependent Variable: TTDT Post-test Score						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected	203.469a	2	101.734	2.297	.102	.014
Model						
Intercept	10771.986	1	10771.986	243.210	.000	433
TTDT Pre-test	175.334	1	175.334	3.959	.047	.012
School Type	21.487	1	21.487	.485	.487	.002
Error	14128.780	319	44.291			
Total	100780.000	322				
Corrected	14332.248	321				
Total						

**Table 8.** ANCOVA Result Comparing the Difference in the Conceptual Knowledge of Public and Private School Students in the Study Area

#### 4. DISCUSSIONS

This study investigated the impact of the open inquiry instructional strategy on students' conceptual knowledge in chemistry, comparing its effectiveness with the demonstration method and examining differences in outcomes between public and private school students. The discussion is presented in alignment with the research questions.

# 4.1. Impact of Open Inquiry on Conceptual Knowledge

The findings indicate that students exposed to the open inquiry instructional strategy demonstrated higher conceptual knowledge in chemistry compared to their pre-test performance. These results align with previous research highlighting the potential of open inquiry to transform science education by fostering student autonomy and improving students' academic achievement, particularly when digital resources are effectively integrated (Ojo and Tijani, 2025). This suggests that the strategy effectively enhances students' ability to explain concepts, establish connections between chemical principles, and apply scientific reasoning. These results align with previous research indicating that inquiry-based learning fosters deeper understanding and active engagement (Feyzioğlu, 2019). By promoting self-directed exploration and critical thinking, open inquiry enables students to construct their knowledge meaningfully, as highlighted by Okafor (2021).

### 4.2. Comparison Between Open Inquiry and Demonstration Strategies

The findings revealed that students taught using the open inquiry strategy significantly outperformed those taught through the demonstration method. The ANCOVA results confirmed that instructional strategies had a substantial effect on students' conceptual knowledge, reinforcing the idea that open inquiry, which is a student-centred learning approach, is more effective than traditional methods that emphasise rote memorisation (Annisa & Rohaeti, 2018). This finding aligns with Onyema et al. (2019), who highlighted that inquiry-based learning facilitates improved academic performance by encouraging active participation and critical thinking. The results suggest that open inquiry provides a superior instructional approach for fostering deep conceptual understanding in chemistry.

#### 4.3. Differences Between Public and Private School Students

The analysis revealed no statistically significant differences in conceptual knowledge between public and private school students when taught using open inquiry. This suggests that the open inquiry instructional strategy is equally effective across different school environments, regardless of disparities in resources. While previous studies have noted challenges such as inadequate facilities in public schools (Alao & Okoliko, 2024; Ogunode et al., 2024), the findings of this study indicate that open inquiry remains a

a. R Squared = .014 (Adjusted R Squared = .008)

viable approach for improving chemistry performance in both settings. This highlights its potential for addressing educational disparities and promoting equitable learning outcomes.

### 4.4. Broader Implications and Significance of the Study

The findings of this study contribute to the growing body of knowledge on effective instructional strategies in senior secondary school chemistry, particularly in fostering conceptual understanding. By demonstrating that the open inquiry instructional strategy significantly enhances students' ability to explain concepts, establish connections, and apply scientific reasoning, this research reinforces the need for student-centred learning approaches in science education.

One key implication of these findings is their potential influence on curriculum design. Traditional curricula often emphasise teacher-centred methods that prioritise content delivery and participation over conceptual understanding. Integrating open inquiry into chemistry curricula could bridge this gap by encouraging active learning and inquiry-driven exploration. Educational policymakers and curriculum developers should consider incorporating structured inquiry activities that gradually transition students towards more independent scientific investigations.

Additionally, the study highlights the importance of teacher training and professional development. Implementing open inquiry effectively requires educators to be well-versed in facilitating student-led investigations while providing appropriate scaffolding. Teacher training programs should therefore emphasise inquiry-based pedagogies, equipping educators with the skills needed to guide students through scientific exploration and critical thinking processes. Furthermore, this study's findings suggest that open inquiry can be effective in diverse school settings, including those with limited resources. This underscores the need for targeted teacher training initiatives that support inquiry-based instruction, particularly in underresourced schools.

Beyond chemistry education, the broader significance of these findings extends to the development of scientific literacy and problem-solving skills essential for Science, Technology, Engineering and Mathematics (STEM) careers. By fostering deeper conceptual understanding, open inquiry equips students with the analytical and reasoning abilities needed to engage meaningfully with scientific concepts beyond the classroom.

### 4.5. Limitations to the Study and Recommendations for Further Studies

While this study provides valuable insights into the effectiveness of the open inquiry instructional strategy in enhancing students' conceptual knowledge in chemistry, certain limitations should be acknowledged. First, the study was conducted within a relatively short duration of six weeks, which may not fully capture the long-term impact of open inquiry on students' learning outcomes. Future research could employ longitudinal studies to examine the retention of conceptual knowledge over extended periods.

Additionally, although the sample size of 322 students from six secondary schools was sufficient for statistical analysis, expanding the study to include a more diverse range of schools across multiple regions could improve the generalisability of the findings. Conducting similar studies in different educational contexts, such as rural versus urban schools or across various socioeconomic backgrounds, would provide deeper insights into the adaptability of open inquiry.

Another area for further research is the role of teacher preparedness in implementing open inquiry effectively. Since this instructional strategy requires a shift from teacher-led instruction to student-driven exploration, future studies could investigate how professional development programs influence teachers' ability to facilitate open inquiry-based lessons. Understanding the challenges teachers face in adopting this approach and identifying strategies to support them would enhance the successful integration of open inquiry into chemistry classrooms.

Moreover, future research could explore the comparative effectiveness of open inquiry in different science subjects beyond chemistry. While this study focused on conceptual knowledge in chemistry, investigating how open inquiry influences students' understanding of physics and biology could provide a more comprehensive view of its applicability across STEM disciplines.

Despite these limitations, this study makes a significant contribution to the field by providing empirical evidence on the benefits of open inquiry. The findings reinforce its potential to improve students' conceptual understanding and suggest that, with adequate teacher training and institutional support, this instructional strategy could play a transformative role in science education. Future studies should build on this foundation by addressing the identified challenges and expanding the scope of inquiry-based learning research.

#### 5. CONCLUSIONS

The study demonstrated that the open inquiry instructional strategy significantly improves students' conceptual knowledge in chemistry compared to the demonstration strategy. The findings suggest that open inquiry can enhance students' conceptual knowledge compared to the demonstration method by promoting active engagement and critical thinking. While the strategy yielded similar results for public and private school students, its effectiveness was not dependent on the type of school, highlighting its potential as a versatile instructional approach. Furthermore, the study was limited to SSS 1 students in Osun State, which may affect generalisability. The use of intact classes in a quasi-experimental design may have introduced uncontrolled variables, and the six-week intervention may not capture long-term effects. Additionally, the focus on three specific topics in chemistry may not fully represent a broader conceptual understanding. However, the sample size used is more than enough to generalise the findings across all secondary schools in Osun State.

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**Research Ethics.** All procedures involving human participants were conducted in accordance with applicable national and institutional regulations and accepted ethical principles. Only schools and students who were willing to participate were included in the study. Institutional ethical approval was not required; nevertheless, research ethics were rigorously followed throughout. Willing participation was obtained from both school administrators and all students (and, where applicable, their parents or guardians) prior to data collection.

**Data Availability Statement.** The data supporting the results reported in this manuscript are based on students' performance records and associated assessment materials. These data are not publicly archived but are available from the corresponding author upon reasonable request.

Conflicts of Interest. The authors declare that there are no conflicts of interest, this article's research, authorship, and publication.

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#### **REFERENCES**

- Alao, B.O. & Okoliko A.M. (2024). Surfacing administrative issues of secondary schools in Nigeria: obstacles for a positive change and improvement in the 21st-century. KWASU International Journal of Education, 7(1). Retrieved from https://www.kije.com.ng/index.php/KIJE/article/view/97/97
- Amadi, U. V., & Nwogu, P. U. J. (2023). The Impact of Funding on Educational Development in Nigeria. *Journal of Education in Developing Areas (JEDA)*, 31(3). Retrieved from https://journals.journalsplace.org/index.php/JEDA/article/view/383
- Annisa, D., & Rohaeti, E. (2018). The effect of inquiry-based learning on students' understanding of the chemical equilibrium concept. *AIP Conference Proceedings*. 17 October 2018; 2021 (1): 080004. Retrieved on August 26, 2024, from, https://doi.org/10.1063/1.5062823
- Feyzioğlu, B. (2019). Effects of inquiry-based learning on students' science literacy skills and interest. *Journal of Education in Science, Environment and Health (JESEH), 5*(1), 22-36. https://doi.org/10.21891/jeseh.478208
- Hasanah, D., Wiji, W., Mulyani, S., & Widhiyanti, T. (2023). Students' Mental Model Profiles on Chemical Bonding Concept Using a Two-Tier Mental Model Diagnostic Test (TDM-Two-Tier). *Jurnal Penelitian Pendidikan IPA*, 9(11), 10466–10474. https://doi.org/10.29303/jppipa.v9i11.3811
- Hodson, D. (2017). Learning science, learning about science, doing science: Different goals demand different learning methods. *International Journal of Science Education*, 35(1), 12-26. https://doi.org/10.1080/09500693.2012.685197

- Hutahaean, E., Pardiana, P., & Hadiyati, Y. (2024). Identify Students' Misconceptions on Electrolysis using Two-Tier Diagnostic Test. *Journal of Research in Environmental and Science Education*, 1(1), 1–11. https://doi.org/10.70232/bvc08237
- Khasawneh, E., Hodge-Zickerman, A., York, C. S., Smith, T. J., & Mayall, H. (2023). Examining the effect of inquiry-based learning versus traditional lecture-based learning on students' achievement in college algebra. *International Electronic Journal of Mathematics Education*, 18(1), em0724. https://doi.org/10.29333/iejme/12715
- Kushta, E., Prenga, D., (2023). Using tests' indexes to improve the assessment of the conceptual knowledge: a case study. *International Journal of Education and Learning Systems*, 8. Retrieved from <a href="https://www.iaras.org/iaras/filedownloads/ijels/2023/002-0002(2023).pdf">https://www.iaras.org/iaras/filedownloads/ijels/2023/002-0002(2023).pdf</a>
- Ogunode, N. J., Adeniyi, D. A., & Ukozor, C. U. (2024). Technical and Vocational Education in Nigeria: Problems and Way Forward. *American Journal of Alternative Education*, 1(2), 23–35. Retrieved from <a href="https://scientificbulletin.com/index.php/AJAE/article/view/40">https://scientificbulletin.com/index.php/AJAE/article/view/40</a>
- Ojo, O. T., & Tijani, B. E. (2025). Impact of Open Inquiry Instructional Strategy on Secondary School Chemistry Students' Academic Achievement: A Student-Centred Approach Leveraging Digital Resources. FUO-Journal of Educational Research, 4(1), 41–51. https://doi.org/10.5281/zenodo.14872972
- Okafor, N. (2016). Culture of peace and care for the Planet Earth as predictors of students' understanding of chemistry concepts. *International Journal of Curriculum and Instruction* 8(1), 36–53.
- Okafor, N. (2021). Enhancing Science Process Skills Acquisition in Chemistry among Secondary School Students through Context-Based Learning. *Science Education International*, 32(4), 323–330. https://doi.org/10.33828/sei.v32.i4.7
- Onyema, E. M., Ogechukwu, U., Anthonia, E. C. D., & Deborah, E. (2019). Potentials of mobile technologies in enhancing the effectiveness of inquiry-based learning approach. *International Journal of Education (IJE), 2*(01), 1-22. https://doi.org10.5121/IJE.2019.1421
- Owolade, A. O., Oladipupo, P. O., Kareem, A. O., & Salami, M. O. (2022). Effectiveness of Guided and Open Inquiry Instructional Strategies on Science Process Skills and Self-Efficacy of Biology Students in Osun State, Nigeria. *African Journal of Teacher Education*, 11(1), 56–74. https://doi.org/10.21083/ajote.v11i1.7014
- Qashdi, A., Susilawati, S., & Rery, R. U. (2022). Development of Chemical Bonding Module Based on Multiple Representation. *Journal of Educational Sciences*, 6(2), 263. https://doi.org/10.31258/jes.6.2.p.263-274
- Rokhmawan, T., Fitriyah, L., Rahmani, A. F. A., Rokhmawati, M. D., & Mukharomah, M. (2023). A Meta-Synthesis Study of Forelearn Apperception Process: Strategy to Overcome Jetlag Issues in Early Learning Activities. Bulletin of Pedagogical Research, 3(2), 103. https://doi.org/10.51278/bpr.v3i2.813
- WAEC, (2020). Chief Examiners Report. Lagos: West African Examinations Council.