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Research Article

Beyond Memorisation: Investigating the Influence of Open Inquiry on Chemistry Students' Scientific Process Skills

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Abstract
The demand for 21st-century skills, particularly critical thinking, problem-solving, and scientific literacy, has necessitated a shift from traditional teacher-centred instruction to student-driven, inquiry-based learning. Open inquiry instructional strategy has been increasingly recognised for its potential to enhance students' engagement and acquisition of process skills in science education. However, limited empirical evidence exists regarding its effectiveness in contexts where traditional methods still dominate. This study examined the effect of the open inquiry instructional strategy on the development of process skills in chemistry among secondary school students. A quasi-experimental research design was employed, involving a pre-test and post-test with a non-equivalent control group of 322 Senior Secondary School 1 (SSS1) students from six selected schools. Data were collected using the Chemistry Process Skills Assessment Test (CPSAT) and analysed using Analysis of Covariance (ANCOVA). The results revealed that students taught using open inquiry performed significantly better in process skills acquisition than those taught using the demonstration method ($F(1, 319) = 74.305$, $p < .001$, $\eta^2 = .189$). Additionally, while private school students had slightly higher mean scores than their public school counterparts, the difference was not statistically significant ($F(1, 319) = 0.823$, $p = .365$), suggesting that open inquiry is effective across different educational contexts. These findings highlight the need to integrate open inquiry into science curricula to promote active learning. The study recommends incorporating open inquiry into science curricula, providing teachers with targeted professional development, ensuring adequate laboratory resources, adopting a blended instructional approach, offering ongoing teacher support and mentorship, and conducting further research to explore its long-term impact and optimise its implementation.

Keywords: Open Inquiry, Science Process Skills, Chemistry Education, Secondary School Students, Student-Centred Approach

1. INTRODUCTION

In the 21st century, the rapid advancement of science and technology has placed a strong emphasis on the development of critical thinking and problem-solving skills among students. Educational systems worldwide are shifting towards student-centred approaches that promote inquiry and hands-on learning, as these skills are essential for success in higher education and professional careers in science and technology. The need for competent problem solvers in an increasingly knowledge-driven world has made the teaching of science process skills a priority in chemistry education. Process skills are essential components of scientific inquiry and involve a range of abilities that enable students to conduct experiments and solve problems effectively. Process skills are essential for aspiring scientists, as they form the foundation of the scientific method. These skills involve a structured and methodical approach to investigating nature in a way that is testable and verifiable. The primary goal is to establish relationships between phenomena, enhancing our understanding of the natural world (Ojo, 2017; Okafor, 2021). These skills are not only crucial in scientific experiments but are also applicable in everyday life, where individuals use them to solve

problems and make decisions. In essence, science process skills guide the sequence of actions researchers follow when conducting scientific investigations. These skills, as stated by Ojo (2017), are grouped into two types, namely: basic and integrated process skills. The basic science process skills that can be developed include six key areas: observing, inferring, measuring, communicating, classifying, and predicting. These skills serve as the foundation for scientific inquiry, helping individuals gather information and make sense of the world around them. In addition, there are integrated science process skills, which are more advanced and build upon the basic skills (Ojo, 2017). These include defining operationally, formulating hypotheses, interpreting data, experimenting, and formulating models.

Student-centred approaches that foster active participation and engagement in the learning process have become more prominent in the evolution of teaching strategies during the 21st century. Historically, chemistry instruction has been characterised by traditional teaching methods, which often involve structured lectures and laboratory exercises. However, these methods have faced criticism for not providing students with sufficient opportunities to interact meaningfully with the subject matter, frequently resulting in rote memorisation rather than a thorough understanding and application of concepts (Annisa & Rohaeti, 2018). Consequently, traditional teaching strategies are increasingly viewed as inadequate for equipping students with the essential skills for scientific inquiry and innovation. For instance, Onyema et al. (2019) argue that teacher-centred strategies limit students' ability to develop independent investigative skills, whereas inquiry-based approaches provide a more effective framework for fostering analytical and reasoning skills.

Process skills are fundamental to scientific inquiry, and open inquiry instructional strategy is particularly effective in fostering these skills. By engaging students in hands-on activities and self-directed investigations, open inquiry helps them develop essential abilities such as observation, hypothesising, and data analysis (Owolade et al., 2022). One of the key strengths of open inquiry is its emphasis on active participation. Students are required to design their experiments, collect and analyse data, and draw conclusions. This process not only enhances their understanding of scientific methods but also builds critical thinking and problem-solving skills. For example, students exploring the factors affecting reaction rates learn to control experiments, report outcomes accurately, and interpret results logically (Okafor, 2021). Furthermore, recent studies by Rokhmawan et al. (2021) and Okero et al. (2021) provide evidence that open inquiry improves students' conceptual understanding and retention of scientific principles better than guided inquiry or traditional demonstration methods. However, gaps remain in understanding how open inquiry compares across different school settings and among students with varying levels of prior knowledge.

In response to these limitations, grounded in the constructivist theories of Piaget and Vygotsky, the open inquiry instructional strategy is an educational approach that empowers students to take control of their learning. It encourages them to formulate their own questions, design and carry out experiments and derive conclusions from their findings. This method promotes student autonomy and engagement, enabling learners to actively take part in their educational journey (Onyema et al., 2019). Research indicates that open inquiry enhances critical thinking, problem-solving, and scientific reasoning skills among students, as they are inspired to explore topics of personal interest and relevance (Owolade et al., 2022). Despite these advantages, some studies, such as Nicol et al. (2024), have reported that open inquiry may not always lead to improvements in mathematical applications within chemistry. Additionally, motivational challenges and lack of resources have been identified as potential barriers to its successful implementation in some educational contexts.

Furthermore, within an open inquiry framework, students are not merely passive recipients of information; rather, they are active participants in their learning process. They begin by posing questions that capture their interest, which showcases their curiosity and specific interests. For example, a student might ask, "What factors affect the equilibrium constant of a reaction?" This question can serve as a foundation for the student to develop experiments, gather pertinent information, and evaluate the results independently. In this context, the teacher's role shifts from being the predominant source of knowledge to that of a facilitator who supports and guides students as they explore their questions (Wang et al., 2022).

Collaboration is another significant aspect of open inquiry that contributes to the development of process skills. Working in groups, students share ideas, critique methods, and refine their approaches. This interaction fosters communication and teamwork, which are vital skills for scientific research and

professional environments (Gillies, 2017). Moreover, open inquiry encourages metacognitive practices, enabling students to evaluate their strategies and improve their experimental designs. This reflective process is integral to developing robust process skills, as it helps students identify areas for improvement and adapt their methods accordingly (Rokhmawan et al., 2021). Over time, these practices lead to greater proficiency in conducting scientific investigations. The iterative nature of open inquiry also ensures that students continuously refine their skills. Each investigation builds on previous experiences, allowing learners to apply their knowledge in increasingly complex scenarios. This progression not only enhances their confidence in conducting experiments but also prepares them for the challenges of higher education and scientific careers (Wijaya et al., 2021).

Despite its potential, the adoption of open inquiry in secondary school chemistry education remains limited. While prior research has demonstrated the benefits of inquiry-based learning, gaps remain regarding its adaptability across different educational settings, its impact on students with varying levels of prior knowledge, and its effectiveness in fostering specific science process skills. This study aims to fill this gap by providing insights into how open inquiry can improve science education and equip students with the skills necessary for the demands of the modern scientific landscape. The study compares the differences in the acquisition of process skills, including designing experiments, observing, formulating hypotheses, and making inferences or conclusions, between students taught using open inquiry and those taught using the demonstration instructional strategy. Additionally, the study compares the acquisition of process skills between public and private school students who are taught using the open inquiry instructional strategy.

1.1. Research Objectives

The specific objectives of the study include:

1. Assess the impact of open inquiry on the acquisition of process skills in chemistry among secondary school students.
2. Compare the differences in the acquisition of process skills between students taught using demonstration and those taught using open inquiry.
3. Compare the acquisition of process skills between public and private school students taught using the open inquiry instructional strategy.

1.2. Research Questions

The study answers the following questions:

1. What is the impact of open inquiry on the acquisition of process skills in chemistry among secondary school students?
2. Is there any difference between the acquisition of process skills of secondary school students taught using demonstration and those taught using open inquiry?
3. What is the difference in the acquisition of process skills between public and private school students taught using the open inquiry instructional strategy?

2. METHODOLOGY

The study adopted a pre-test, post-test non-equivalent control group quasi-experimental research design. This design consisted of two groups formed from six intact classes, categorised based on the instructional strategy used: Open Inquiry and Demonstration. The Open Inquiry Instructional Guide (OIIG) and Demonstration Instructional Guide (DIG) served as stimulus instruments for delivering instruction, both adapted from the study of Ojo & Tijani (2025). Teachers in both groups were trained on the use of the respective guides. The Experimental Group was taught using the OIIG by the researcher, assisted by the regular chemistry teachers in the experimental schools, while the Control Group was taught using the DIG by the regular chemistry teachers in the control schools. Pre-tests for process skills were administered before the intervention, followed by post-tests after the treatment to assess students' process skills acquisition. The schematic diagram of the design is presented below:

Table 1. Schematic Diagram of the Design for the Study

Experimental Group	Independent Variable	Control Group
O_1	X_1	O_3
O_2	X_2	O_4

Where

O_1 and O_3 are pre-tests of the experimental group and control group respectively.

O_2 and O_4 are post-tests of the experimental group and control group respectively.

X_1 = Treatment using open inquiry strategy.

X_2 = Treatment using demonstration strategy.

2.1. Population

The target population for this study comprised senior secondary school students in Osun State, while the accessible population focused on Senior Secondary School One (SSS I) science students in Osun East Senatorial District. This region was selected due to its mix of public and private schools, ensuring representation of students from diverse academic backgrounds. Additionally, while some schools may have had exposure to student-centred instructional strategies, the extent and consistency of their implementation remain uncertain. This variation provides an opportunity to systematically investigate the influence of open inquiry on students' scientific process skills, particularly in a context where traditional teacher-centred methods remain prevalent.

2.2. Sample and Sampling Techniques

The sample for the study was 322 Senior Secondary School 1 (SSS 1) science students. The study employed a multistage sampling technique to select the sample for the study. Out of the three senatorial districts, one senatorial district was selected using a simple random sampling technique. The Ife East and Ife Central Local Government Areas (LGAs) were chosen from the selected senatorial district through a simple random sampling technique. Furthermore, a purposive sampling technique was used to select six schools from the selected Local Government Areas. The purposive selection of schools was done to ensure the following:

1. Selection of schools with adequate laboratory facilities and instructional materials, which are essential for the assessment of students' acquisition of process skills.
2. Consideration of schools that are willing and ready to participate in the study.
3. Selection of co-educational schools.

Table 2. Distribution of Selected Schools by Treatments, School Type and Number of Students

Group	Name of School	School Type	Treatment type	No of Students
A (E_1)	School I	Public	Open Inquiry	70
A(E_2)	School II	Public	Open Inquiry	64
A(E_3)	School III	Private	Open Inquiry	32
B (C_1)	School IV	Public	Demonstration	60
B(C_2)	School V	Public	Demonstration	76
B(C_3)	School VI	Private	Demonstration	20
			Total	322

Additionally, a simple random sampling technique was employed to select one intact SSS 1 science class in each of the schools. This approach ensures that all science classes in the six selected schools have an equal chance of being selected, thereby minimising bias. The six intact classes were assigned to two groups, containing 3 intact classes each, using a simple random sampling technique. Students in experimental group A (E_1, E_2, E_3) were exposed to the open inquiry instructional strategy while those in control group B (C_1, C_2, C_3) were taught using the demonstration instructional strategy. The intervention was conducted over six weeks, covering topics such as the concept of atoms, molecules, and ions; the concept of elements, compounds, and mixtures; and separation techniques. These topics were selected because intact classes were used for the study, making it necessary to align with the existing school scheme

of work during the treatment period. This approach ensured that the study did not disrupt the schools' curriculum while allowing for a natural integration of the instructional strategies being investigated. Table 2 below shows the number of students in the selected schools and their assignment to treatments.

Table 2 shows the distribution of the sample by treatment, school type, and number of students. The total sample of 322 students comprised 166 students in the Open Inquiry group (134 from public schools and 32 from private schools) and 156 students in the Demonstration group (136 from public schools and 20 from private schools).

2.3. Research Instrument

The Chemistry Process Skills Assessment Test (CPSAT) was used to collect data for the study. The CPSAT is a structured assessment tool designed by the researcher following the established integrated process skills framework of the National Science Education Standards (NSES) (1995) (National Research Council et al., 1996). Specifically, it was used to assess the student's ability to design experiments, observe, formulate hypotheses, and make inferences or conclusions. By measuring these skills, the CPSAT provides insight into how effectively students can apply their theoretical knowledge in practical settings. The instrument is structured into two sections to ensure comprehensive data collection and evaluation. Section A gathers demographic information about the student's gender and school type. Section B focuses on assessing the students' process skills and consists of 5 items on the four process skills. The scoring system for Section B follows the practical marking guides of the West African Examination Council and allocates 6 marks for a correct answer in each item, resulting in a total score of 30 marks for the entire assessment.

2.4. Validity and Reliability of Instrument

The validity of the Chemistry Process Skills Rating Scale (CPSAT) is grounded in its alignment with the established integrated process skills framework of the National Science Education Standards (NSES) which outlines essential science process skills, including designing experiments, observing, formulating hypotheses, and making inferences or conclusions crucial for effective scientific inquiry and education. The instrument was developed based on well-defined skills in experimental design, observation, hypothesis development and making inferences, ensuring that each item reflects these competencies. Content validity was established through expert reviews in the field of science education to confirm that the statements effectively measure the intended skills.

The reliability of the Chemistry Process Skills Assessment Test (CPSAT) was evaluated using Cohen's Kappa, which measures the level of agreement between two independent raters. This method was chosen to assess the consistency of the scoring process across multiple evaluators, ensuring the objectivity of the instrument. The inter-rater reliability analysis yielded a Cohen's Kappa coefficient ($\varkappa$) of 0.892, with an asymptotic standard error of 0.030 and a p-value of 0.000, indicating statistical significance. According to Landis and Koch (1977), a Kappa value between 0.81 and 1.00 represents an "almost perfect" agreement, confirming the high reliability of the CPSAT. The crosstabulation analysis showed that the majority of scores assigned by both raters were in agreement, with only minor discrepancies observed. These results affirm that the CPSAT provides consistent and reliable assessments of students' scientific process skills. The high inter-rater agreement suggests that the instrument is effective in minimising subjective bias in scoring and can be reliably used to measure students' ability to design experiments, observe, formulate hypotheses, and make inferences or conclusions.

2.5. Methods of Data Analysis

The data were analysed using the Statistical Package for the Social Sciences (SPSS) version 27.0. Analysis of Covariance (ANCOVA) was utilised throughout to evaluate the acquisition of process skills among students. This included comparing the effectiveness of demonstration and open inquiry instructional strategies, with pre-test scores entered as covariates to control for baseline differences. By incorporating pre-test scores, the analysis effectively isolated the influence of the instructional strategies on the post-test process skills. Additionally, it was also used to examine differences in the acquisition of process skills

between public and private school students exposed to the open inquiry instructional strategy. This approach allowed for an in-depth understanding of the role of school type while adjusting for initial variations in performance. All analyses were conducted at a significance level of $p < 0.05$, ensuring the reliability and validity of the results.

3. RESULTS

Research Question 1: *What is the impact of open inquiry on the acquisition of process skills in chemistry among secondary school students?*

The descriptive statistics in Table 3 demonstrate the impact of open inquiry on the acquisition of process skills in chemistry among secondary school students. The mean CPSAT post-test score for students taught using the open inquiry instructional strategy was 19.80 with a standard deviation of 6.569, while those taught using the demonstration strategy had a mean score of 13.57 with a standard deviation of 6.222. This difference highlights that the open inquiry method significantly enhances process skills compared to the demonstration approach. The total mean score for all students was 16.78, with a standard deviation of 7.112, reflecting overall performance trends. The higher mean score and slightly larger variability in the open inquiry group suggest that this approach not only improves process skills but also accommodates diverse learning outcomes more effectively than the demonstration method.

Table 3. Descriptive Statistics on the Impact of Open Inquiry on the Acquisition of Process Skills of Secondary School Chemistry Students in the Study Area

Dependent Variable: CPSAT Post-test Score			
Instructional Strategies	**Mean**	**Std. Deviation**	**N**
Demonstration	13.57	6.222	156
Open Inquiry	19.80	6.569	166
Total	16.78	7.112	322

Research Question 2: *Is there any difference between the acquisition of process skills of secondary school students taught using demonstration and those taught using open inquiry?*

Table 4: Analysis of Covariance on Comparison of Process Skills of Students Taught Using Demonstration and Open Inquiry Strategy in the Study Area

Dependent Variable: CPSAT Post-test Score						
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	3514.997[a]	2	1757.499	44.068	.000	.216
Intercept	10379.914	1	10379.914	260.266	.000	.449
Process Skill Pre-test	398.913	1	398.913	10.002	.002	.030
Treatment	2963.418	1	2963.418	74.305	.000	.189
Error	12722.347	319	39.882			
Total	106897.000	322				
Corrected Total	16237.345	321				

a. R Squared = 0.216, (Adjusted R Squared = 0.212)

To determine whether there was a statistically significant difference in the acquisition of process skills between students taught using the demonstration instructional strategy and those taught using the open inquiry instructional strategy, an Analysis of Covariance (ANCOVA) was conducted. The results are presented in Table 4. The corrected model was statistically significant, $F_{(2, 319)} = 44.068$, $p < .001$, $\eta^2 = .216$, indicating that the model accounted for approximately 21.6% of the variance in the post-test scores of the Chemistry Process Skills Assessment Test (CPSAT). The process skill pre-test was also statistically significant, $F_{(1, 319)} = 10.002$, $p = .002$, $\eta^2 = .030$, suggesting that students' prior process skill levels had a small but meaningful effect on their post-test scores. The type of instructional strategy (treatment) had a statistically significant effect on students' process skill acquisition, $F_{(1, 319)} = 74.305$, $p < .001$, $\eta^2 = .189$. This indicates that 18.9% of the variance in post-test scores was explained by the instructional strategy used.

The adjusted R² value of .212 suggests that the model explains approximately 21.2% of the variability in students' post-test scores, confirming the robustness of the findings.

Table 5. Bonferroni Post-hoc Analysis of Students' Conceptual Knowledge in CPSAT Based on Instructional Strategies

Treatment (I)	Treatment (J)	Mean Difference (I-J)	Sig.b	95% Confidence Interval for Differenceb	
				Lower Bound	Upper Bound
Control	Open Inquiry	-6.083*	<0.001	-7.471	-4.694
Open Inquiry	Control	6.083*	<0.001	4.694	7.471

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

A Bonferroni post-hoc analysis (Table 5) was conducted to further examine the differences between the two instructional strategies. The results indicate that students taught using the open inquiry instructional strategy scored significantly higher on the CPSAT than those taught using the demonstration instructional strategy, with a mean difference of 6.083, $p < .001$. The 95% confidence interval (CI) [-7.471, -4.694] confirms that the difference is statistically significant and not due to chance.

Research Question 3: *What is the difference in the acquisition of process skills between public and private school students taught using the open inquiry instructional strategy?*

Analysis of Covariance (ANCOVA) was conducted. The results are presented in Table 6 and Table 7.

Table 6. Descriptive Statistics on Differences in the Acquisition of Process Skills Between Public and Private School Students Taught Using Open Inquiry in the Study Area.

Dependent Variable: CPSAT Post-test Score			
School Type	Mean	Std. Deviation	N
Public	16.63	7.136	270
Private	17.58	7.002	52
Total	16.78	7.112	322

The descriptive statistics presented in Table 6 show the mean post-test scores for process skills acquisition among students taught using the open inquiry instructional strategy in public and private schools. Public school students have a mean score of 16.63 with a standard deviation of 7.136, while private school students have a slightly higher mean score of 17.58 with a standard deviation of 7.002. While the mean score for private school students is higher, the difference between the two groups is not large. The total mean score for all students is 16.78, with a standard deviation of 7.112. These descriptive statistics suggest that, on average, private school students perform slightly better than public school students in acquiring process skills when taught using the open inquiry instructional strategy. However, further statistical analysis using ANCOVA, as presented in Table 7, was used to determine whether this difference is statistically significant.

Table 7. Analysis of Covariance on Differences in the Process Skills of Public and Private School Students Taught Using Open Inquiry in the Study Area

Dependent Variable: CPSAT Post-test Score					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	591.938a	2	295.969	6.035	0.003
Intercept	9137.963	1	9137.963	186.317	0.000
Process Skill Pre-test	552.505	1	552.505	11.265	0.001
School Type	40.359	1	40.359	0.823	0.365
Error	15645.406	319	49.045		
Total	106897.000	322			
Corrected Total	16237.345	321			

a. R Squared = .036 (Adjusted R Squared = .030)

An Analysis of Covariance (ANCOVA) was performed to evaluate whether school type (public vs. private) significantly influenced students' CPSAT post-test scores after accounting for pre-test scores. The corrected model was statistically significant, $F_{(2, 319)} = 6.04$, $p = .003$, indicating that the model accounted for some variability in students' post-test scores. Additionally, the process skill pre-test was a significant covariate, $F_{(1, 319)} = 11.27$, $p = .001$, suggesting that students' prior knowledge influenced their post-test performance. However, school type was not a significant predictor of post-test scores, $F_{(1, 319)} = 0.82$, $p = .365$, indicating that, after adjusting for pre-test scores, the difference between public and private school students' process skill acquisition was not statistically significant. The effect size ($\eta^2 = .036$, adjusted $R^2 = .030$) suggests that only 3.6% of the variance in post-test scores was explained by the model, with school type contributing negligibly.

The study found that students taught using the open inquiry instructional strategy significantly outperformed those taught using the demonstration method in acquiring process skills. The open inquiry approach proved to be more effective in fostering critical thinking, problem-solving, and collaboration skills necessary for scientific inquiry. The findings also revealed that while private school students had slightly higher mean scores than public school students, the difference was not statistically significant, indicating that open inquiry can be effectively implemented across different school types. The study further established that the open inquiry strategy provides an interactive and student-centred learning experience that enhances the development of scientific process skills better than the traditional demonstration method. These results suggest that integrating open inquiry into science curricula can improve students' engagement and proficiency in scientific investigations.

4. DISCUSSION

The findings of this study reinforce the efficacy of the open inquiry instructional strategy in enhancing students' acquisition of process skills in chemistry. The results align with previous research demonstrating that inquiry-based learning fosters critical thinking, problem-solving, and experimental competencies more effectively than traditional instructional approaches (Owolade et al., 2022). The significant improvement in students' process skills under the open inquiry approach corroborates the findings of Nicol et al. (2024), who reported that inquiry-based experimentation improved learners' conceptual understanding and inquiry skills. However, Nicol et al. (2024) also noted that inquiry learning did not significantly enhance students' mastery of mathematical components, suggesting that additional instructional support may be required to address this challenge.

The significant difference between the two instructional strategies (open inquiry and demonstration) further validates the findings of Onyema et al. (2019), who noted that constructivist approaches like open inquiry provide a superior framework for skill acquisition compared to teacher-centred methods. The findings of this study reinforce the view that while the demonstration method may effectively transmit factual knowledge, it falls short in fostering higher-order skills such as problem-solving and scientific reasoning. Additionally, Anil (2023) had previously criticised traditional strategies for their limitations in developing critical thinking skills. The current findings substantiate these criticisms by demonstrating that open inquiry not only improves students' process skills but also addresses the cognitive demands of modern science education.

Although private school students achieved a slightly higher mean post-test score than public school students, the difference was not statistically significant. This finding contrasts slightly with Rokhmawan et al. (2021), who suggested that resource disparities between public and private schools could influence the efficacy of inquiry-based strategies. However, the lack of significance in this study indicates that, when properly implemented, open inquiry can be effective across diverse educational contexts. The results also align with Gillies (2017), who emphasised the importance of teacher facilitation in collaborative and inquiry-based learning environments. In this study, the consistent performance across school types suggests that teacher competence in implementing open inquiry might mitigate institutional differences.

The findings also highlight that open inquiry is adaptable across different school types, as no significant difference was observed between public and private school students. This is consistent with Owolade et al. (2022), who found no significant difference in the science process skills of students exposed to open and guided inquiry strategies. This suggests that the efficacy of inquiry-based methods is not limited

by institutional factors, making them a viable approach for widespread implementation in secondary school chemistry education.

The broader implications of these findings for educational practice are substantial. Educators can leverage open inquiry to cultivate students' independent learning abilities, enhancing their engagement and deepening their conceptual understanding of scientific phenomena. This aligns with the conclusions of Omoniyi (2019), who demonstrated that the Process-Oriented Guided Inquiry Learning (POGIL) strategy significantly improved students' performance in chemistry, suggesting the efficacy of inquiry-based learning strategies in improving students' acquisition of process skills. Additionally, Eluket et al. (2019) emphasised the role of experimental work in knowledge acquisition, reinforcing the argument that hands-on, inquiry-driven activities are essential for developing students' process skills.

Despite its advantages, the study acknowledges potential challenges associated with the implementation of open inquiry. Nicol et al. (2024) observed that while inquiry-based strategies improved students' confidence and attitudes towards experimentation, they also resulted in a degree of demotivation. This suggests that a blended approach, incorporating elements of both demonstration and inquiry-based learning, may be beneficial in maximising student engagement. Similarly, Okero et al. (2021) recommended the integration of Science Process Skills Teaching Approaches (SPSTA) to enhance students' achievement in chemistry practicals, underscoring the importance of structured guidance alongside student-directed exploration.

In light of these findings, open inquiry strategy should be integrated into chemistry curricula to enhance students' acquisition of process skills and overall scientific literacy. Teachers should receive targeted professional development to effectively implement inquiry-based methods, ensuring that students receive the necessary guidance to navigate the complexities of self-directed learning. Furthermore, adequate resources and laboratory facilities should be provided to facilitate hands-on experimentation, addressing barriers that may hinder the adoption of inquiry-based approaches. Overall, this study contributes to the growing body of evidence supporting the use of inquiry-based instructional strategies in science education. By fostering critical thinking, problem-solving, and investigative skills, open inquiry has the potential to equip students with the competencies necessary for academic success and future scientific endeavours.

5. CONCLUSION AND RECOMMENDATIONS

The findings demonstrate that the open inquiry instructional strategy is more effective than traditional demonstration methods in developing students' process skills. Open inquiry fosters critical thinking, problem-solving, and collaboration skills essential for scientific inquiry. The lack of significant differences between public and private school students indicates the adaptability of open inquiry across various educational contexts when implemented effectively. These results advocate for integrating student-centred learning approaches like open inquiry into the science curriculum to enhance skill acquisition and meet the demands of modern science education.

Based on the findings of this study, the following recommendations are made to improve the acquisition of process skills in secondary school science education:

1. Open inquiry should be incorporated into science curricula to enhance student-centred learning, critical thinking, and problem-solving skills.
2. Teachers should receive targeted training to effectively implement open inquiry instructional strategies.
3. Schools should be equipped with sufficient laboratory resources to support hands-on inquiry-based learning.
4. A combination of open inquiry and traditional demonstration methods should be adopted to maintain student engagement and address potential learning challenges.
5. Ongoing support, mentoring, and collaboration opportunities should be provided to improve teachers' effectiveness in implementing open inquiry strategies.

Future studies should examine the long-term effects of open inquiry on student performance and strategies for addressing challenges, such as mathematical applications in science experiments.

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