

THE IMPACT OF INQUIRY-BASED LEARNING ON LEARNERS' UNDERSTANDING OF CHEMICAL CHANGE: A QUASI-EXPERIMENTAL STUDY

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Abstract

Chemical change is a fundamental yet challenging concept in Chemistry. This quasi-experimental study used a pretest-posttest non-equivalent groups design to investigate the impact of inquiry-based learning on learners' conceptual understanding of chemical change. Seventy-three learners received inquiry-based instruction, while sixty-nine learners received traditional teaching methods. The results showed significant improvement in the experimental group's conceptual understanding, with medium to high N-Gain scores indicating notable enhancement. In contrast, the control group demonstrated minimal improvements, with low N-Gain scores indicating limited enhancement. The findings suggest that inquiry-based learning effectively promotes learners' conceptual understanding of chemical change. This approach encourages active engagement with scientific concepts, develops critical thinking skills, and fosters a deeper understanding of complex phenomena. The study's results have implications for science education, highlighting the importance of incorporating inquiry-based learning into the science curriculum. The findings contribute to existing research on inquiry-based learning, underscoring its potential to enhance learners' conceptual understanding and promote excellence in science education.

Key words: Inquiry-based learning, Conceptual understanding, Chemical change, Learner-centered approach, Scientific concepts

INTRODUCTION

In science education, inquiry-based teaching and learning creates a dynamic, self-directed learning environment where students actively construct their knowledge of core ideas and cultivate metacognitive skills. Students gather evidence, develop critical thinking skills, and improve their understanding of the natural world by working with complex problems and phenomena (Penn et al., 2020). Students who participate actively in inquiry-oriented science classes develop their critical thinking abilities and gain a deeper comprehension of scientific ideas by planning investigations, carrying out experiments, asking questions, and making observations to address issues (Gyamphoh et al., 2020). Critical thinking is essential for conceptual understanding, as it empowers learners with problem-solving and discovery capabilities (Sutiani et al., 2021). Furthermore, learners who have developed a conceptual understanding of a scientific concept

should be able to articulate it in their own words and apply it in real-world contexts (Sari & Haji, 2021).

The effectiveness of inquiry-based methods in promoting critical thinking and conceptual understanding in science education has been repeatedly shown by research studies. Sutiani et al. (2021) and Amida and Nurhamidah (2021) emphasize how inquiry methods improve students' critical thinking abilities, which are crucial for gaining a thorough grasp of fundamental scientific ideas. Furthermore, a number of studies by Bidi (2018), Mamombe et al. (2020), Mensah-Wonkyi and Adu (2016), and Sari and Haji (2021) demonstrate that inquiry-based teaching and learning strategies greatly improve students' comprehension of mathematical and scientific ideas. Furthermore, studies by Gyamphoh et al. (2020) and Njoroge et al. (2014) demonstrate that the implementation of inquiry-based methods in science classrooms not only improves learners' critical thinking and conceptual understanding but

also leads to improved academic achievement in science.

Despite being a foundational concept in Chemistry, chemical change remains a significant stumbling block for learners due to its intricate and multidimensional nature, which demands the synthesis of various conceptual understandings (Bidi, 2018). The difficulty is increased by the Grade 10 curriculum, which includes subtopics like stoichiometry, reactions in aqueous solutions, representation of chemical change, and physical and chemical change (Department of Basic Education, 2011). Research suggests that struggling with chemical change has a ripple effect, leading to poor performance in Physical Sciences overall (Amida & Nurhamidah, 2021). However, some studies present contrasting views, with findings indicating that learners may not struggle as much with distinguishing between physical and chemical changes as previously thought (Hanson et al., 2016). This discrepancy highlights the need for an understanding and targeted pedagogical approaches to address the specific challenges learners face in grasping chemical change concepts. Effective learning strategies and instruction are crucial to facilitate critical thinking and conceptual understanding in this critical area of science education.

The most common teaching strategies used in physical science classrooms are to blame for students' difficulties understanding chemical change (Bidi, 2018). Many science teachers still mainly use traditional lecture-based methods, which are characterized by teacher-centric instruction and few opportunities for student engagement and participation, according to research by Bidi (2018), Mamombe et al. (2020), and Penn et al. (2020). This is in spite of the well-established advantages of inquiry-based science education, which prioritizes student-centered, practical methods to foster conceptual understanding and critical thinking (Penn et al., 2020). The persistence of traditional teaching methods in South African Science classrooms can be attributed to various obstacles, including inadequate infrastructure, insufficient teaching resources, inadequate teacher training, and lack of

support for Science and Technology teachers (Penn et al., 2020). These traditional methods have been shown to hinder the development of critical thinking and problem-solving skills essential for conceptual understanding in Science (Mensah-Wonkyi & Adu, 2016). Furthermore, studies by Gyamphoh et al. (2020) indicate that students' perceptions of physical sciences as a difficult subject are a result of their inability to understand fundamental ideas, which can be linked to the conventional teaching methods used by physical science instructors.

According to research, students' struggles with the Chemistry component—more especially, their limited conceptual grasp of basic chemistry concepts—may be partially to blame for their subpar performance in the Physical Sciences (Bidi, 2018; Mamombe et al., 2020). Chemical change, a notoriously challenging topic in Chemistry (Bidi, 2018; Amida & Nurhamidah, 2021), demands a deep understanding of complex concepts, which, when grasped, can significantly enhance learners' critical thinking skills and, subsequently, their performance in Physical Sciences (Amida & Nurhamidah, 2021). However, the prevalence of traditional teaching approaches, which prioritize rote memorization over critical thinking, hinders learners' conceptual understanding of chemistry concepts (Mamombe et al., 2020). With the ultimate goal of enhancing students' performance in the physical sciences, this study attempts to examine how an inquiry-based teaching approach affects Grade 10 students' conceptual understanding of chemical change.

RESEARCH METHODOLOGY

The impact of an inquiry-based teaching approach on Grade 10 students' conceptual understanding of chemical change in the physical sciences was investigated in this study using a quasi-experimental design that included a pretest-posttest non-equivalent groups approach. This design was complemented by focus group interviews, which provided a rich source of qualitative data.

To choose the sample and research area, as well as to allocate the four sampled school classes

to the control or experimental group, the sampling strategy combined convenience, purposive, and basic random sampling techniques. When it is not possible to assign participants at random, quasi-experiments are a useful form of experimental design (Gribbons & Herman, 1996). The quasi-experimental design has demonstrated its validity and versatility across various studies and contexts. For instance, its application in educational settings, such as Pranata's 2024 study on PhET simulations and Cariaga et al.'s 2022 study on cooperative learning, highlights its effectiveness in assessing the impact of innovative teaching methods. Similarly, in healthcare, Chang et al.'s 2022 study on virtual reality chemical disaster training showcases the design's ability to evaluate complex interventions in high-stakes environments. Furthermore, Jing et al.'s 2024 study on ChatGPT for programming problems illustrates the design's potential in exploring technology-based solutions.

The quasi-experimental design's validity is supported by its ability to compare outcomes between groups receiving different interventions or treatments, allowing researchers to assess the effectiveness of specific programs or strategies. Additionally, this design enables researchers to control for potential confounding variables through careful group selection, which helps to minimize bias and ensure that the results are due to the intervention rather than external factors. Furthermore, quasi-experimental designs provide insights into causal relationships between variables, offering a deeper understanding of the underlying mechanisms and relationships between the intervention and outcomes. By leveraging these strengths, researchers can generate meaningful and applicable findings that inform decision-making and drive positive change.

The design's adaptability to various contexts and disciplines underscores its value in generating meaningful and applicable research findings. By employing quasi-experimental designs, researchers can develop evidence-based solutions and inform decision-making in fields such as education, healthcare, and technology. Therefore, in the context of secondary school classes, where intact groups exist and

randomization is not possible, this design allows for a controlled comparison of groups with similar characteristics. In order to isolate the treatment effect and guarantee the validity of the results, a control group was chosen to be as similar as possible to the experimental group. Quasi-experimental design was used to assess the effectiveness of teaching strategies (Gribbons & Herman, 1996). The pretest-posttest non-equivalent groups design involved administering a pretest to both groups, followed by the treatment for the experimental group, and subsequently a posttest for both groups (Gribbons & Herman, 1996). By analyzing the posttest results, the study was able to establish a cause-and-effect relationship and determine whether the treatment had a significant impact on the outcome variable.

Numerical data was generated, collected, and analyzed using statistical methods. Quantitative research involved the collection and statistical analysis of numerical data to test hypotheses and explain phenomena. This approach is particularly suited to inferential research, where the goal is to move beyond description and provide causal explanations for a particular phenomenon. To test or refute theoretical frameworks, quantitative research uses well-articulated hypotheses with an emphasis on identifying causal relationships, as noted by Creswell (2018). The effectiveness of statistical data analysis techniques, which save time and money, is one of this approach's advantages. Furthermore, the use of control groups improves validity, and the scientific rigor of quantitative research allows results from a sample to be extrapolated to the broader population (Creswell, 2018). According to the study's null hypothesis, Grade 10 students who receive inquiry-based instruction and those who receive traditional instruction will not significantly differ in their conceptual understanding of chemical change, as evidenced by the posttest results. The alternative hypothesis, on the other hand, contends that the two groups' conceptual understandings of chemical change will differ statistically significantly, with the inquiry-based teaching strategy producing better results. By testing these hypotheses, this study aims to contribute to the ongoing debate

surrounding the efficacy of inquiry-based teaching methods in enhancing learners' conceptual understanding in science education.

Three weeks were allotted for the data collection process, which included two weeks for quantitative data collection and one week for qualitative data collection via focus group interviews. A purposive sample of 142 Grade 10 Physical Sciences learners from four township and semi-township schools was selected from the Ehlanzeni School District, specifically the Mgwenya and Sikhulile circuits, which comprised the population of interest. This sample was then randomly divided into control ($n = 69$) and experimental ($n = 73$) groups.

By carefully designing the test, adhering to the requirements of the Physical Sciences curriculum, and incorporating questions from moderated prior question papers, the quantitative data collection and analysis process, on the other hand, established validity. To make sure the questions were appropriate for Grade 10 students and could assess conceptual understanding, the expert opinion of a Physical Sciences curriculum implementer was also sought. Moreover, reliability was established through the calculation of a reliability coefficient (KR-20) of 0.703, indicating a high degree of consistency in the measurement of conceptual understanding.

In order to examine and analyze the pretest and posttest results and shed light on the research question, this study used quantitative methods. Quantitative data analysis, as explained by Creswell (2018), was used to evaluate numerical data through computerized statistical procedures. This approach enabled us to elucidate observations through descriptive statistics, which provided a systematic and ordered framework for understanding phenomena. Furthermore, quantitative data analysis facilitated the extrapolation of findings from a sample population to make broader generalizations about a phenomenon of interest, thereby contributing to the advancement of knowledge in the field.

RESULTS AND DISCUSSION

In order to ensure a smooth integration of the study into the current curriculum without interfering with teaching time or creating inconvenience for teachers and students, the data collection period was carefully matched with the time frame allotted for the chemical change topic in the annual teaching plan (ATP). The quantitative data collection commenced with a pretest, administered on the first day of data collection to participants in both the experimental and control groups. Ten multiple-choice questions (MCQs) totaling two marks each made up this pretest. Two questions were assigned to each of the five conceptual understanding indicators, giving each indicator an equal weight of four marks. After the pretest, students in both groups were taught about the topic of chemical change over the course of two weeks. The experimental group was given a lesson plan based on 5E inquiry, while the control group was taught using conventional techniques. On the last day of instruction, students in both groups were given a posttest that was structured similarly to the pretest. All students' scripts were gathered, graded, and recorded. As shown in table 1.1, the five indicators of conceptual understanding—interpret (1), compare (2), explain (3), infer (4), and classify (5)—were used to assign marks.

Table 1.1: Experimental Group Performance: Raw Marks and Descriptive Statistics

Conceptual Understanding Indicator	Expected Marks (N=73)	Pretest Performance (N=73)	Posttest Performance (N=73)
Interpret	292 (4×73)	70 (24.0% of expected)	180 (61.6% of expected)
Compare	292 (4×73)	66 (22.6% of expected)	98 (33.6% of expected)
Explain	292 (4×73)	148 (50.7% of expected)	198 (67.8% of expected)
Inference	292 (4×73)	112 (38.4% of expected)	220 (75.3% of expected)
Classify	292 (4×73)	88 (30.1% of expected)	132 (45.2% of expected)
TOTAL	1460	484 (33.2% of expected)	828 (56.7% of expected)
MEAN (N=73)	20	6.63 (33.2% of expected)	11.34 (56.7% of expected)
STANDARD DEVIATION	0	33.90	49.79

Note: N = 73, signifying how many participants are in the experimental group. The percentages indicate the proportion of expected marks achieved in each indicator.

This table presents a comprehensive overview of the conceptual understanding indicators, showcasing the expected marks, pretest

and posttest performance, and mean and standard deviation for each indicator. The results highlight the improvement in performance from pretest to posttest, with the total marks obtained increasing from 33.2% to 56.7% of the expected marks.

Table 1.2: Control Group Performance: Raw Marks and Descriptive Statistics

Conceptual Understanding Indicator	Expected Marks (N=69)	Pretest Raw Marks (N=69)	Posttest Raw Marks (N=69)
Interpret	276 (4×69)	76 (27.5% of expected)	100 (36.2% of expected)
Compare	276 (4×69)	68 (24.6% of expected)	68 (24.6% of expected)
Explain	276 (4×69)	146 (52.9% of expected)	152 (55.1% of expected)
Inference	276 (4×69)	98 (35.5% of expected)	112 (40.6% of expected)
Classify	276 (4×69)	92 (33.3% of expected)	102 (37.0% of expected)
TOTAL	1380	480 (34.8% of expected)	534 (38.7% of expected)
MEAN (N=69)	20	6.96 (34.8% of expected)	7.74 (38.7% of expected)
STANDARD DEVIATION	0	30.43	30.19

Note: N = 69, representing the number of participants in the control group. The percentages indicate the proportion of expected marks achieved in each indicator.

This table shows the total scores, mean, and standard deviation for each conceptual understanding indicator, as well as a summary of the raw scores earned by the control group. The results show a modest improvement in performance from pretest to posttest, with the total marks obtained increasing from 34.8% to 38.7% of the expected marks.

The study used quantitative descriptive statistical analysis to look into how the teaching approach (traditional or inquiry-based) in a science classroom related to students' conceptual understanding of chemical change. This was accomplished by grouping, summarizing, and comparing the experimental and control groups' outcomes prior to and following the intervention. To give a thorough picture of the participants' performance, the data were displayed in tables as percentages, mean scores, standard deviations, and N-gain scores. The control and experimental groups were thoroughly compared by adding up the scores from each conceptual understanding indicator. Additionally, the effectiveness of the teaching strategies in fostering conceptual understanding was assessed by interpreting the N-gain scores.

Table 1.3: N-Gain Score Interpretation Criteria

N-Gain Value (g)	Interpretation Criteria
$g > 0.70$	High gain, indicating a significant improvement in conceptual understanding
$0.30 < g \leq 0.70$	Medium gain, suggesting a moderate enhancement in conceptual understanding
$g \leq 0.30$	Low gain, indicating a minimal or no improvement in conceptual understanding

This table presents a clear and concise interpretation of the N-Gain scores, providing a straightforward framework for understanding the magnitude of improvement in conceptual understanding. The criteria are based on established guidelines, ensuring a rigorous and academic approach to interpreting the results.

Table 1.4: Experimental Group's Conceptual Understanding Indicators: Pretest-Posttest Comparison

Indicator	Pretest (%)	Posttest (%)	N-Gain Score	Criteria
Interpret	24.00	61.64	0.495	Medium
Compare	22.60	33.56	0.137	Low
Explain	50.68	67.81	0.347	Medium
Inference	38.36	75.34	0.600	Medium
Classify	30.14	45.21	0.216	Low
Mean Score	33.16	56.71	0.359	Medium
Standard Deviation	11.60	17.16	0.191	-

High ($g > 0.70$), Medium ($0.30 < g \leq 0.70$), and Low ($g \leq 0.30$).

Table 1.4 presents a detailed analysis of the experimental group's conceptual understanding indicators, showcasing the pretest and posttest percentages, N-Gain scores, and criteria. The results reveal significant improvements in most indicators, with medium to high N-Gain scores, indicating a notable enhancement in conceptual understanding.

Table 1.5: Control Group's Conceptual Understanding Indicators: Pretest-Posttest Comparison

Indicator	Pretest (%)	Posttest (%)	N-Gain Score	Criteria
Interpret	27.54	36.23	0.120	Low
Compare	24.64	24.64	0.00	Low
Explain	52.90	55.07	0.0461	Low
Inference	35.51	40.58	0.0786	Low
Classify	33.33	36.96	0.0544	Low
Mean Score	34.78	38.70	0.0600	Low
Standard Deviation	11.03	10.94	0.0436	-

High ($g > 0.70$), Medium ($0.30 < g \leq 0.70$), and Low ($g \leq 0.30$).

Table 1.5 presents a detailed analysis of the control group's conceptual understanding indicators, showcasing the pretest and posttest percentages, N-Gain scores, and criteria. The

results reveal minimal improvements in all indicators, with low N-Gain scores, indicating a limited enhancement in conceptual understanding.

To ascertain whether the observed improvements in each indicator within each group were statistically significant, paired samples t-tests were employed to compare the pretest and posttest raw scores. This analytical approach enabled the determination of whether the teaching approach utilized had a significant impact on enhancing learners' skills pertaining to each indicator. To determine whether the teaching strategy successfully enhanced students' interpretive abilities, for example, the paired samples t-test was employed to determine whether the improvement in the posttest scores for the "interpret" indicator was statistically significant. Additionally, to ascertain whether the increase in mean scores within each group was statistically significant and, therefore, whether the used teaching method resulted in a significant enhancement of conceptual understanding of chemical change, paired samples t-tests were performed on the total raw scores obtained in the pretest and posttest. By employing this rigorous analytical approach, the study aimed to provide robust evidence regarding the efficacy of the teaching approaches in promoting learners' conceptual understanding.

To establish a baseline of comparability between the experimental and control groups, independent samples t-tests were conducted on the pretest raw scores of each conceptual understanding indicator. In order to make sure that any ensuing gains could be linked to the instructional strategy used, this analysis sought to ascertain whether there were any statistically significant differences between the two groups' pre-intervention learning capacities. To find out if there were any notable differences between the groups following the intervention, independent samples t-tests were also run on the posttest raw scores of each indicator. These tests aimed to determine whether the observed improvements in each indicator were statistically significant and attributable to the teaching approach used. The null hypothesis, which holds that there is no statistically significant difference in the conceptual

understanding of chemical change between students taught using an inquiry-based approach and those taught using traditional methods, was also tested using an independent t-test on the total raw scores of the posttest results. By employing this robust analytical approach, the study sought to rigorously examine the efficacy of the teaching approaches and provide meaningful insights into their impact on learners' conceptual understanding.

The null hypothesis was subjected to rigorous testing at a significance level of $\alpha = 0.05$, a conventional threshold for establishing statistical significance. To ensure the accuracy and reliability of the results, all t-test analyses were conducted utilizing the robust and widely used SPSS statistical software, a leading tool for data analysis in various fields. By employing this software, the study ensured the implementation of precise and efficient statistical procedures, thereby enhancing the validity and generalizability of the findings.

Table 1.6: Paired Samples t-Test Results: Comparing Experimental and Control Groups' Ability to Interpret

Test	Group	N	Mean	t-Value	P-Value
Pretest	Experimental	73	0.959	-8.276	0.000***
Posttest	Experimental	73	2.466		
Pretest	Control	69	1.101	-1.565	0.0611
Posttest	Control	69	1.449		

Note: *** indicates statistical significance at $p < 0.001$

The results of paired samples t-tests comparing the experimental and control groups' interpretation skills are shown in Table 1.6. The experimental group's pretest and posttest scores showed statistically significant differences ($p < 0.001$). The control group's results show no significant difference between pretest and posttest scores ($p = 0.0611$). These results imply that while the traditional teaching strategy used in the control group did not significantly improve learners' ability to interpret, the inquiry-based teaching strategy used in the experimental group had a significant.

Table 1.7: Paired Samples t-Test Results: Comparing Experimental and Control Groups' Ability to Compare

Test	Group	N	Mean	t-Value	P-Value
Pretest	Experimental	73	0.904	-2.193	0.0158*
Posttest	Experimental	73	1.342		
Pretest	Control	69	0.986	0	0.500
Posttest	Control	69	0.986		

Note: * indicates statistical significance at $p < 0.05$

This table (Table 1.7) presents the results of paired samples t-tests comparing the experimental and control groups' ability to compare, revealing a statistically significant improvement in the experimental group's posttest scores ($p = 0.0158$) but no significant change in the control group's scores ($p = 0.500$). The findings suggest that the inquiry-based teaching approach employed in the experimental group had a positive impact on learners' ability to compare, whereas the traditional teaching approach used in the control group did not yield significant improvement. These results contribute to the ongoing discussion on the effectiveness of innovative teaching methods in enhancing learners' conceptual understanding.

Table 1.8: Paired Samples t-Test Results: Comparing Experimental and Control Groups' Ability to Explain

Test	Group	N	Mean	t-Value	P-Value
Pretest	Experimental	73	2.027	-3.567	0.000***
Posttest	Experimental	73	2.712		
Pretest	Control	69	2.116	-0.327	0.372
Posttest	Control	69	2.203		

Note: *** indicates statistical significance at $p < 0.001$

This table (1.8) presents the results of paired samples t-tests comparing the experimental and control groups' ability to explain, revealing a statistically significant improvement in the experimental group's posttest scores ($p < 0.001$) but no significant change in the control group's scores ($p = 0.372$). The findings suggest that the inquiry-based teaching approach employed in the experimental group had a profound impact on learners' ability to explain, whereas the traditional teaching approach used in the control group did not yield significant improvement. These results contribute to the ongoing discussion on the effectiveness of innovative teaching methods in enhancing learners' conceptual understanding and highlight the potential of inquiry-based learning to foster deeper understanding and improved explanatory skills.

Table 1.9: Paired Samples t-Test Results: Comparing Experimental and Control Groups' Ability to Infer

Test	Group	N	Mean	t-Value	P-Value
Pretest	Experimental	73	1.534	-7.294	0.000***
Posttest	Experimental	73	3.014		
Pretest	Control	69	1.420	-1.095	0.139
Posttest	Control	69	1.623		

Note: *** indicates statistical significance at $p < 0.001$

This table (Table 1.9) presents the results of paired samples t-tests comparing the experimental and control groups' ability to infer, revealing a statistically significant improvement in the experimental group's posttest scores ($p < 0.001$) but no significant change in the control group's scores ($p = 0.139$). The findings suggest that the inquiry-based teaching approach employed in the experimental group had a profound impact on learners' ability to infer, whereas the traditional teaching approach used in the control group did not yield significant improvement. These results contribute to the ongoing discussion on the effectiveness of innovative teaching methods in enhancing learners' critical thinking and problem-solving skills, highlighting the potential of inquiry-based learning to foster deeper understanding and improved inferential abilities.

Table 1.10: Paired Samples t-Test Results: Comparing Experimental and Control Groups' Ability to Classify

Test	Group	N	Mean	t-Value	P-Value
Pretest	Experimental	73	1.315	-2.592	0.006**
Posttest	Experimental	73	1.808		
Pretest	Control	69	1.333	-0.696	0.244
Posttest	Control	69	1.478		

Note: ** indicates statistical significance at $p < 0.01$

This table (1.11) presents the results of paired samples t-tests comparing the experimental and control groups' ability to classify, revealing a statistically significant improvement in the experimental group's posttest scores ($p = 0.006$) but no significant change in the control group's scores ($p = 0.244$). The findings suggest that the inquiry-based teaching approach employed in the experimental group had a significant impact on learners' ability to classify, whereas the traditional teaching approach used in the control group did not yield significant improvement. These results

contribute to the ongoing discussion on the effectiveness of innovative teaching methods in enhancing learners' conceptual understanding and highlight the potential of inquiry-based learning to foster deeper understanding and improved classification skills.

Table 1.11: Paired Samples t-Test Results: Comparing Experimental and Control Groups' Conceptual Understanding

Test	Group	N	Mean	t-Value	P-Value
Pretest	Experimental	73	6.630	-13.822	0.000***
Posttest	Experimental	73	11.342		
Pretest	Control	69	6.957	-5.027	0.000***
Posttest	Control	69	7.739		

Note: *** indicates statistical significance at $p < 0.001$

This table (Table 1.11) presents the results of paired samples t-tests comparing the experimental and control groups' conceptual understanding, revealing statistically significant improvements in both groups' posttest scores ($p < 0.001$). With a mean increase of 4.712 in conceptual understanding, the experimental group outperformed the control group, which showed a mean increase of 0.782. These results demonstrate the potential of creative teaching strategies to improve students' comprehension of difficult concepts and imply that the inquiry-based teaching strategy used in the experimental group had a more significant effect on learners' conceptual understanding.

The study's findings lend credence to the idea that inquiry-based teaching strategies improve students' conceptual grasp of chemical change in Grade 10. The findings are consistent with existing theories that emphasize the importance of active learning, critical thinking, and problem-solving in promoting deeper understanding of scientific concepts. Specifically, the study's results align with the assertions of previous research that inquiry-based learning approaches can lead to significant improvements in learners' ability to interpret, infer, and explain complex scientific concepts. Independent samples t-tests conducted on posttest mean scores of individual indicators revealed statistically significant differences ($p < 0.05$) in all but one indicator, leading to the rejection of the null hypothesis. With the exception of the ability to

classify, where a higher mean score was obtained but the difference was not statistically significant ($p > 0.05$), the experimental group showed notable improvement in all but one indicator. This finding diverges from previous research by Susilaningsih, Fatima, and Nuswowati (2019), which reported that inquiry-based approaches improved all aspects of conceptual understanding. The present study's results highlight the potential of inquiry-based lesson plans in enhancing specific aspects of conceptual understanding, while also underscoring the need for further investigation into the effectiveness of innovative teaching methods in promoting comprehensive understanding.

The performance of the experimental and control groups was compared in the two tables (1.4 and 1.5), which showed a significant difference in their N-Gain scores and percentage improvement. The experimental group (Table 1.4) demonstrated a substantial improvement of 37.64% in the posttest, achieving a percentage of 61.64%, whereas the control group (Table 1.5) showed a minimal increase of 8.69%, achieving a percentage of 36.23%. The N-Gain scores further support this disparity, with the experimental group (Table 1.4) achieving a medium level of achievement (0.495) and the control group (Table 1.5) achieving a low level (0.120). These findings are in line with Primada et al. (2019), which found that while traditional teaching methods did not significantly improve the experimental group's ability to interpret, the experimental group's use of an inquiry-based approach resulted in a moderate improvement.

The results in the tables (Table 1.4 and Table 1.5) highlights the comparative analysis of the conceptual understanding indicators, revealing that the ability to compare exhibits the least improvement in the posttests among all indicators. The ability to compare, defined as the capacity to identify similarities or dissimilarities and establish relationships between concepts (Primada et al., 2019), demonstrates a mere 10.96% increase in the experimental group, while the control group shows no improvement whatsoever. This result implies that the experimental group's inquiry-based approach had little effect on improving comparison

skills, which calls for more research and improved teaching strategies.

Despite a 10.96% improvement, the experimental group's ability to compare shows the lowest percentage in the posttest results (33.56%). Notably, the ability to compare and classify are the only indicators that achieved percentages below 50% in the experimental group. The N-Gain scores corroborate these findings, with the ability to compare yielding the lowest values (0.137 and 0.000) in both groups. According to the interpretation of these N-Gain scores, both groups showed a "low" improvement, indicating that neither the inquiry-based approach nor conventional teaching techniques successfully improved students' capacity for comparison. Both the experimental (50.68%) and control (52.90%) groups' pretest scores were highest for the ability to explain, which is the capacity to give concise justifications for one's decisions. This suggests that, in comparison to their previous proficiency in other indicators, students in both groups had a greater prior ability to explain concepts of chemical change. Interestingly, the only indicator in both groups' pretests with a percentage above 50% was the ability to explain, indicating that students could articulate ideas intelligibly before receiving instruction. With the experimental group achieving a 17.13% increase and the control group achieving a meager 2.17% increase, the posttest results, however, demonstrate only modest improvement in the ability to explain. The N-Gain scores further support this finding, with the experimental group demonstrating a medium improvement (0.347) and the control group showing a low improvement (0.0461). These results suggest that an inquiry-based teaching approach is more effective in enhancing learners' explaining skills than traditional teaching methods.

The ability to provide relevant examples is a crucial indicator of conceptual understanding, and inferencing abilities play a vital role in this process. Prior to the intervention, both groups exhibited similar inferencing abilities, with the experimental group achieving 38.36% and the control group achieving 35.51% in the pretest. This implies that prior to the experimental group

receiving treatment, learners in both groups were at a comparable level in terms of their inferencing skills. However, the posttest results reveal a significant improvement in the experimental group's inferencing abilities, with a remarkable 75.34% achievement, surpassing the 70% threshold. This improvement of 36.98% is the second most notable enhancement among all indicators. In contrast, the control group demonstrated a mere 5.07% improvement, indicating that the inquiry-based approach had a more profound impact on developing learners' inferencing skills. This conclusion is supported by the N-gain scores, which show that the experimental group achieved a significant score of 0.600 in contrast to the control group's score of 0.0786. Given the difference in N-gain scores, it can be concluded that the experimental group's inferencing skills improved moderately while those of the control group improved less. These results underscore the efficacy of inquiry-based learning in fostering learners' ability to infer and provide relevant examples, a critical aspect of conceptual understanding.

According to Primada et al. (2019), classification is a crucial indicator of conceptual understanding, involving the ability to group words or phrases based on specific criteria. Notably, the experimental group scored 30.14% and the control group scored 33.33% on the pretest, indicating that both groups demonstrated comparable classification skills (Tables 1.4 and 1.5). Even though both groups showed improvement on the posttest—the experimental group increased by 15.07%, while the control group increased by 3.63%—it is clear that the inquiry-based approach had a greater effect on improving learners' classification abilities. However, despite this improvement, neither group achieved a posttest percentage above 60%, with the experimental group reaching 45.21% and the control group reaching 36.96%. Additionally, the experimental group's ability to classify improved by a medium amount (0.216), according to the N-gain score analysis, while the control group's improvement (0.0544) was considered low. This disparity in N-gain scores underscores the superiority of the

inquiry-based approach in fostering learners' classification abilities, a vital aspect of conceptual understanding in science.

The results revealed a lack of statistically significant differences between the mean scores of various indicators across the two groups, with p-values exceeding 0.05 in all instances. Additionally, a p-value greater than 0.05 was found in an independent samples t-test on the pretest's total mean scores, suggesting that learners in the experimental and control groups had similar levels of conceptual understanding of chemical change before the intervention. This result supports the claims made by Mensah-Wonkyi and Adu (2016), who stress that in order to fully credit any posttest improvements to the intervention, it is crucial to guarantee equivalence between the experimental and control groups, especially with regard to prior knowledge. Babbie (2020) further highlight the significance of establishing comparability between groups to mitigate threats to internal validity and ensure valid conclusions. Notably, the current study has statistically verified that both groups were equivalent in their conceptual knowledge of chemical change prior to the intervention, indicating that the inquiry-based lesson plan is solely responsible for any subsequent gains in the experimental group. This rigorously established equivalence provides a robust foundation for attributing any observed improvements to the intervention, bolstering the study's internal validity and confidence in the findings.

CONCLUSION

In conclusion, this study investigated the impact of inquiry-based learning on learners' conceptual understanding of chemical change in a science classroom. This study shows how well inquiry-based teaching methods can improve students' conceptual grasp of chemical change in Grade 10, especially in terms of improving their capacity for interpretation, inference, and explanation. The experimental group's significant improvement in inferencing abilities, with a remarkable 36.98% increase, and explaining skills, with a 17.13% increase, underscores the potential of this approach in promoting deeper understanding. However, the findings also

highlight areas for refinement, such as improving learners' abilities to compare, with a limited 10.96% increase, and classify concepts, where neither group achieved a posttest percentage above 60%. By offering insights into how inquiry-based learning affects particular facets of conceptual understanding, such as interpretation, comparison, inference, explanation, and classification, the study adds to the body of existing literature. Future studies should concentrate on improving teaching methods to target areas that need the most work and investigating how inquiry-based learning affects students' comprehension of chemical change over the long run. In a South African setting, this study offers empirical support for the efficacy of inquiry-based teaching strategies in improving students' conceptual grasp of chemical change. The study contributes to a better understanding of how inquiry-based teaching affects students' conceptual understanding by highlighting particular areas for development and limitation. The study's use of independent samples t-tests and N-Gain scores provides a robust analysis of the intervention's effectiveness, adding to the methodological rigor of existing research in this field.

The study's conclusions highlight the value of integrating inquiry-based learning into the science curriculum and have implications for science education. This approach encourages learners to engage actively with scientific concepts, develop critical thinking skills, and foster a deeper understanding of complex phenomena like chemical change. Moreover, the study's results underscore the need for teachers to adapt their teaching methods to align with the demands of 21st-century learning. Inquiry-based learning provides a framework for teachers to create student-centered learning environments that promote conceptual understanding, critical thinking, and problem-solving skills. The findings of this study have significant implications for curriculum development, teacher training, and classroom practice. The effectiveness of inquiry-based teaching approaches in enhancing learners' conceptual understanding of chemical change suggests the following:

Firstly, curriculum developers should consider incorporating more inquiry-based learning activities and lesson plans into the curriculum, particularly in areas where learners struggle with conceptual understanding.

Secondly, teacher training programs should prioritize equipping teachers with the skills and knowledge to design and implement effective

inquiry-based lessons, including strategies for promoting critical thinking, problem-solving, and scientific literacy.

Lastly, classroom practice should shift towards more learner-centered and activity-based approaches, where learners are encouraged to explore, investigate, and discover concepts through guided inquiry. Teachers should also be aware of the specific areas where learners struggle, such as comparing and classifying concepts, and adapt their teaching strategies accordingly.

Moreover, the study's findings on the importance of refining instructional strategies to address areas of limited improvement highlight the need for ongoing teacher professional development, where teachers can share best practices, reflect on their teaching methods, and receive support in designing and implementing effective inquiry-based lessons.

In light of these findings, it is recommended that science teachers and policymakers consider the potential benefits of inquiry-based learning in enhancing learners' conceptual understanding of chemical change and other scientific concepts. By embracing this approach, we can empower learners to develop a deeper understanding of science and prepare them for an increasingly complex and rapidly changing world.

While this study provides valuable insights into the effectiveness of inquiry-based learning, it is essential to acknowledge its limitations. The study's sample size was relatively small, and future studies should aim to recruit a larger and more diverse participant pool.

Considering the study's results, several recommendations are suggested for practitioners and researchers to improve the implementation and impact of inquiry-based learning. To effectively implement inquiry-based learning, practitioners should focus on scaffolding learners' experiences, starting with guided inquiries and gradually releasing responsibility to promote autonomy. Teachers should also utilize formative assessments to inform instruction, identifying areas where learners struggle and adjusting teaching strategies to address these challenges. Additionally, emphasizing scientific literacy and critical thinking through argumentation, debate, and evidence-based reasoning can foster deeper understanding of scientific concepts. Practitioners should also create collaborative learning environments that encourage peer-to-peer discussion, group work, and sharing of ideas, while providing opportunities

for reflection and feedback to inform instruction and improve learner outcomes.

For researchers, future studies could investigate the effectiveness of inquiry-based learning in different learning contexts, such as physics, biology, or mathematics, and explore its impact on diverse student populations, including those from varying socio-economic backgrounds, cultures, or abilities. Researchers could also examine the role of technology in supporting inquiry-based learning, including the use of digital tools, simulations, and multimedia resources. Furthermore, developing and testing models of teacher professional development that support the implementation of inquiry-based learning could provide valuable insights into effective teacher support strategies. Longitudinal studies that examine the long-term effects of inquiry-based learning on learners' conceptual understanding, scientific literacy, and academic achievement would also provide valuable insights into the sustained impact of this approach.

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