Journal of Chemical Learning Innovation
Vol. 1, No. 2, December 2024, pp. 147~154
ISSN: 3063-0886, DOI:10.37251/jocli.v1i2.3075

Inquiry-Based Chemistry Learning: An Effective Strategy to Strengthen Students' Conceptual Understanding

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Article Info

Article history:

Received Oct 28, 2024
Revised Nov 29, 2024
Accepted Dec 29, 2024
OnlineFirst Dec 31, 2024

Keywords:

Chemistry
Colloids
Conceptual Understanding
Inquiry Learning
Learning Outcomes

ABSTRACT

Purpose of the study: This study aims to determine whether inquiry-based chemistry learning has an effect on students' conceptual understanding, especially on colloid material, by comparing learning outcomes before and after the application of inquiry-based learning.

Methodology: The study used a one-group pretest-posttest weak experimental design, purposive sampling technique with a sample of 40 students, instruments in the form of multiple-choice tests and questionnaires. Data analysis used the Liliefors normality test, Fisher's homogeneity test, t-test, and N-Gain quantitatively.

Main Findings: The results of the study showed an increase in students' conceptual understanding after inquiry-based learning, with the average score increasing from pretest to posttest. The N-Gain value of 0.46 is included in the moderate category, dominated by the moderate category. Statistical tests showed that t count > t table, indicating a significant effect of inquiry-based learning.

Novelty/Originality of this study: This study emphasizes specific conceptual understanding in inquiry-based chemistry learning on colloids. The novelty lies in the empirical evidence of direct classroom implementation, which demonstrates how a structured inquiry process can significantly improve students' conceptual construction, resulting in moderate improvement.

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1. INTRODUCTION

Chemistry learning is a complex field of study, involving abstract, symbolic concepts, and microscopic phenomena [1], [2]. Many students struggle to grasp chemical concepts deeply because learning often focuses on memorization [3], [4]. As a result, students' conceptual understanding tends to be weak and short-lived. This condition impacts students' ability to apply concepts in everyday life. Therefore, learning strategies are needed that can increase students' active engagement in the learning process [5], [6].

One approach considered effective in chemistry learning is inquiry-based learning [7], [8]. This approach emphasizes students' independent search and discovery of knowledge through scientific activities. Students are encouraged to ask questions, conduct experiments, and draw conclusions based on the data obtained. Thus, learning is not solely teacher-centered but also fully engages students [9], [10]. This is expected to help students build a stronger understanding of concepts.

Inquiry-based learning also provides opportunities for students to develop critical and analytical thinking skills [11], [12]. In the process, students are trained to connect theory with direct practice. This active engagement allows students to understand chemical concepts more deeply and meaningfully [13], [14]. Furthermore, inquiry-based learning can stimulate students' curiosity about the chemical phenomena around them [7], [15]. This makes learning more engaging and relevant.

However, in reality, many chemistry lessons in schools still use conventional methods [16], [17]. Teachers tend to deliver material through lectures without actively involving students in the learning process [18], [19]. This results in students simply receiving information without fully understanding the concepts. As a result, students have difficulty explaining the concepts they have learned [20], [21]. This situation highlights the need for innovation in chemistry learning strategies.

Several previous studies have shown that inquiry-based learning can improve student learning outcomes [22], [23]. However, most of these studies focused on general learning outcomes, rather than specifically on conceptual understanding [24], [25]. Furthermore, there is a variation in research findings, indicating that the effectiveness of inquiry learning is influenced by its context and implementation. This indicates a gap in research regarding the influence of inquiry learning on students' conceptual understanding in greater depth. Therefore, further research is needed to examine this issue.

The novelty of this study lies in its specific focus on examining students' conceptual understanding in inquiry-based chemistry learning. It also emphasizes how the inquiry process can help students develop concepts systematically [26], [27]. Furthermore, this research was conducted in an actual learning context, providing a concrete picture of classroom implementation. The urgency of this research is based on the importance of improving the quality of chemistry learning, which is not only oriented towards outcomes but also towards the process of understanding. Therefore, the research results are expected to contribute to the development of more effective learning strategies.

Based on this description, this research is crucial to address the challenges faced in chemistry learning. Conceptual understanding is a fundamental aspect that students must possess to fully master the material. Therefore, a learning approach is needed that can significantly enhance this understanding. This research is expected to provide empirical evidence regarding the effectiveness of inquiry-based learning. The primary objective of this study is to determine whether inquiry-based chemistry learning has an impact on students' conceptual understanding.

2. RESEARCH METHOD

2.1. Type of Research

This study employed a weak experimental design as its research approach. The design used was a one-group pretest-posttest design, involving one group of research subjects [28], [29]. In this design, measurements were taken before and after the treatment was administered. This aimed to observe changes that occurred as a result of the treatment. An overview of the research design is presented below.

Table 1. Research Design

Pretest	Treatment	Posttest
O_1	X	O_2

The description in this research design is that X represents the treatment given to the research subjects, namely the application of inquiry-based chemistry learning. O_1 indicates the pretest score obtained by students before being given the inquiry-based learning treatment. Meanwhile, O_2 is the posttest score obtained by students after participating in inquiry-based chemistry learning. Thus, the comparison between O_1 and O_2 is used to observe changes in students' conceptual understanding as a result of the treatment given.

2.2. Sampling Techniques

The sampling technique used in this study was purposive sampling, which involves selecting a sample based on specific considerations and objectives tailored to the research needs [30], [31]. This technique was chosen to ensure the sample is truly relevant to the focus of the research. Therefore, the sample is expected to provide data that aligns with the research objectives.

The target population in this study was all students of Pamulang 1 State Senior High School who were taking chemistry classes. Meanwhile, the accessible population in this study was all 11th-grade students of Pamulang 1 State Senior High School in the same semester, specifically those studying the concept of colloids. This accessible population was determined to focus the research on material relevant to the treatment provided.

The research sample used was one class, namely class XI-A, with 40 students. This class was selected based on specific considerations that align with the research needs, such as the suitability of the material being studied and classroom conditions that support inquiry-based learning. Therefore, the sample was considered representative of the conditions studied.

2.3. Data Collection Techniques

The data collection technique in this study used a written test as the primary instrument for obtaining research data. The written test was used to measure students' conceptual understanding before and after being given an inquiry-based chemistry learning treatment [32], [33]. Furthermore, this study also used a questionnaire as supporting data. The questionnaire was used to obtain additional information related to students' responses to the learning process that had been implemented. Thus, the data obtained was not only quantitative but also supported by supporting data that enriched the research results.

2.4. Research Instruments

The instruments used in this study consisted of two types: learning instruments and data collection instruments. Both types of instruments were designed to support the research implementation and obtain data in accordance with the research objectives. The learning instruments included the tools used in the learning process, namely the syllabus and the Lesson Plan. In addition, Student Worksheets were used, designed to encourage student active participation in learning activities [34], [35]. These Student Worksheets served as a guide for students in conducting inquiry activities, thus helping them to understand concepts more deeply.

The data collection instruments consisted of a learning outcome test and a questionnaire. The learning outcome test was used to measure students' conceptual mastery and understanding of the colloid material. The test used was an objective multiple-choice test administered before and after the treatment. Through this test, researchers were able to quantitatively determine changes in students' conceptual understanding. In addition to the test, a questionnaire was also used to obtain supporting data. This questionnaire aimed to determine students' responses to the learning process that had been implemented. Furthermore, it was used to gather information regarding the effect of inquiry-based learning on students' conceptual understanding of colloid material. The data obtained from this questionnaire served as secondary data, complementing the primary test results. The outline of the learning outcome test instrument used in this study can be seen in Table 2.

Table 2. Learning Outcome Test Instrument Grid

No.	Indicator	Cognitive Level					Amount
		C1	C2	C3	C4	C5	
1.	Classify coarse suspensions, true solutions, and colloids based on experimental data (homogeneity/heterogeneity, filtration and the Thyndall effect).	2, 4, 6	1, 3, 5				6
2.	Grouping types of colloids based on the dispersed phase and dispersing medium.	7, 8, 9, 10, 11, 12, 13					7
3.	Explain the process of making colloids.	14	15, 16, 17, 18, 19				6
4.	Describe the properties of colloids (Tyndall effect and coagulation) through experiments.	20, 21, 22	23, 24, 25, 26, 27				8
5.	Describe the role of colloids in the cosmetics, food and pharmaceutical industries.			28, 29, 30			3
	Amount	14	8	8			30

2.5. Data Processing and Analysis Techniques

The data processing techniques in this study were conducted through several stages. The first stage was editing, which involved re-examining the data obtained from the field, both from observation sheets and written test answers. This check aimed to ensure that all data had been entered correctly according to the instructions provided. Following this, scoring was performed, assigning a score to each indicator item in the research instrument. The next stage was tabulating, which presented the data in tabular form, expressed as frequencies and percentages to facilitate analysis.

Before using the instrument, a calibration process was conducted through a series of tests. These tests included validity, reliability, discriminatory power, and difficulty level. Validity tests aimed to determine the instrument's accuracy in measuring what it was supposed to measure [36], [37]. An instrument was considered valid if the correlation coefficient value obtained was greater than the value in the table. Therefore, only valid items were used in the study.

Next, a reliability test was conducted to determine the instrument's consistency. A reliable instrument indicates that the measurement results obtained are consistent and reliable [38], [39]. Furthermore, a discriminatory power test was conducted to determine the ability of each item to differentiate between high-ability and low-ability students. The discriminating power classification was used to determine the quality of the questions, ranging from poor to excellent. Therefore, only questions with good discriminating power were used in the study.

A difficulty level test was also conducted to determine the level of difficulty of each question. The difficulty index was calculated based on the ratio of the number of students who answered correctly to the total number of students. Questions were categorized as easy, medium, and difficult based on the index value obtained. A good level of difficulty is in the medium category, optimally measuring student ability. Therefore, questions were selected selectively to meet the expected criteria.

The data analysis technique in this study was quantitative. The collected data was then analyzed to answer the research problem formulation and test the research hypotheses. The initial stage of the analysis was conducting prerequisite tests, namely calculating the raw scores for the pretest and posttest and constructing a frequency distribution of the data. Furthermore, the mean, median, and mode values were calculated to describe the characteristics of the data. This step aims to provide an initial overview of the data obtained.

Next, a normality test was conducted to determine whether the data were normally distributed. The normality test in this study used the Liliefors test with specific criteria for decision-making. If the data is normally distributed, the analysis can proceed to the next stage. Furthermore, a homogeneity test using Fisher's exact test is performed to determine the equality of variance between data groups. The results of this test determine whether the data originate from a homogeneous population.

The final stage of the analysis is hypothesis testing using a t-test. This test is used to determine whether there is a significant difference between pretest and posttest scores. Furthermore, a normalized gain calculation is performed to determine the level of improvement in students' conceptual understanding after the learning process. Gain scores are categorized as high, medium, and low based on specific criteria. Thus, the results of this analysis can provide an overview of the effectiveness of inquiry-based chemistry learning in improving students' conceptual understanding.

3. RESULTS AND DISCUSSION

3.1. Normality Test

A normality test is performed to determine whether the data obtained comes from a normally distributed population. In this study, the normality test was performed on pretest and posttest scores. The Lilliefors test was used for normality testing because it was appropriate for the research sample. The results of this test served as the basis for determining subsequent analysis steps, particularly in hypothesis testing. The results of the normality test are presented in the following table:

Table 3. Results of Pretest and Posttest Normality Tests

Score Data	N	A	L_{count}	L_{table}	Conclusion
Pretest	40	0.05	0.1241	0.1401	H_0 accepted
Posttest	40	0.05	0.1230	0.1401	H_0 accepted

Based on the normality test results table, the pretest data obtained an L_0 value of 0.1241, while the L_t value was 0.1401 at a significance level of $\alpha = 0.05$ with a sample size (n) of 40. Because the L_{count} value is smaller than L_{table} ($0.1241 < 0.1401$), then H_0 is accepted, which means the pretest data comes from a normally distributed population. Meanwhile, the posttest data obtained an L_0 value of 0.1230 and L_t of 0.1401 at the same significance level. The comparison results show that $L_{count} < L_{table}$ ($0.1230 < 0.1401$), so H_0 is also accepted. Thus, it can be concluded that the posttest data comes from a normally distributed population.

3.2. Homogeneity Test

The homogeneity test is conducted to determine whether the data obtained comes from a homogeneous population or not. The test criteria used are H_o is accepted if the calculated F value is smaller than Ftable, and H_o is rejected if the calculated F value is greater than Ftable. If H_o is accepted, then the research data comes from a homogeneous population, whereas if H_o is rejected, then the data comes from a non-homogeneous population. In this study, the homogeneity test was conducted on the pretest and posttest data using the Fisher exact test. The results of this test are used to ensure the equality of variances of the two data sets before further hypothesis testing is carried out. Thus, the results of the homogeneity test are one of the important requirements in data analysis. The results of the homogeneity test calculation are presented in the following table:

Table 4. Results of Homogeneity Testing with Fisher's Exact Test

α	Value Data	Amount	Varians	F_{count}	F_{table}	Conclusion
0.05	Pretest	40	27.97	1-56	1.69	H_0 accepted
	Posttest	40	43.76			

Based on the results of the homogeneity test, the Fcount value was 1.56, while the F_{table} value at a significance level of α = 0.05 with a numerator of 40 and a denominator of 40 degrees of freedom was 1.69. Because the F_{count} value is smaller than the Ftable (1.56 < 1.69), H0 is accepted. Thus, it can be concluded that both data have the same variance or are homogeneous.

3.3. N-Gain Test

Student learning outcomes can be analyzed to determine the extent to which inquiry-based chemistry learning has influenced students' understanding of the concept of colloids. This analysis is conducted by comparing the results of the initial (pretest) and final (posttest) tests. This comparison aims to determine whether there has been an increase in conceptual understanding after the learning intervention. Furthermore, the improvement in learning outcomes is analyzed using the N-Gain value. By calculating the N-Gain, the level of improvement in student understanding can be more measurably determined.

Table 5. Students' N-Gain Results

	Pretest	Posttest	Gain
Average	50.45	72.75	0.46

Based on the table, it can be seen that the majority of students are in the moderate category. Two students, or 5%, fall into the high category. Meanwhile, 37 students, or 97.5%, fall into the moderate category, and one student, or 2.5%, falls into the low category. This data indicates that students' conceptual understanding is predominantly at the moderate level. The N-gain score categorization diagram can be seen in the following figure:

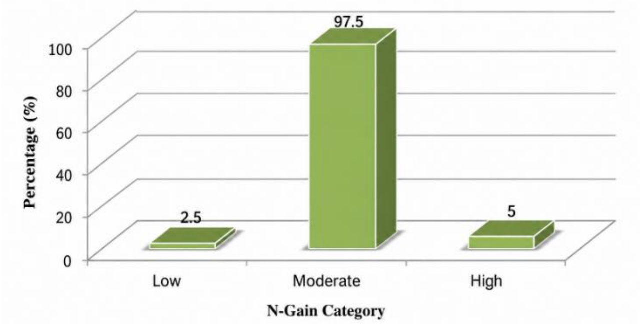

Figure 1. Percentage Diagram of N-Gain Score Categorization

3.4. Hypothesis Testing

Hypothesis testing was conducted to determine whether there was an effect of inquiry-based chemistry learning on students' conceptual understanding. In this study, hypothesis testing used the t-test. The testing criteria were that Ha was accepted if the calculated t value was greater than the t-table, and Ha was rejected if the calculated t value was smaller than the t-table. If Ha was accepted, it could be concluded that there was an effect of inquiry-based chemistry learning on students' conceptual understanding. Conversely, if Ha was rejected, there was no effect of inquiry-based chemistry learning on students' conceptual understanding. This hypothesis testing was conducted on pretest and posttest score data. The results of the t-test calculation are presented in the following table.

Table 6. Results of Hypothesis Testing with T-Test

N	α	t_{count}	t_{table}	Conclusion
40	0.01	4.84	2.68	H_a accepted

Based on the results of the hypothesis testing, the t-count value was 4.48, while the t-table value at a significance level of α = 0.05 with 40 degrees of freedom was 2.68. Because the t-count value was greater than the t-table (4.48 > 2.68), Ha was accepted. Thus, it can be concluded that there is an influence of inquiry-based chemistry learning on students' conceptual understanding.

Inquiry-based chemistry learning in this study demonstrated a crucial role in developing students' deeper conceptual understanding. This occurs because the inquiry approach positions students as active participants in the learning process. Through activities such as observing, asking questions, and conducting experiments, students not only receive information but also construct their own knowledge [40], [41]. This process enables meaningful learning, making the concepts learned easier to understand and remember. Thus, inquiry-based learning can bridge the gap between abstract chemistry concepts and students' real-life experiences.

Furthermore, inquiry-based learning also contributes to the development of higher-order thinking skills. During the inquiry process, students are required to analyze data, draw conclusions, and connect various concepts they have learned [42], [43]. These activities indirectly train students' critical and logical thinking skills. These abilities are crucial in chemistry learning, which demands conceptual understanding, not just memorization. Therefore, the inquiry approach not only improves conceptual understanding but also equips students with scientific thinking skills.

The implementation of inquiry-based learning also has a positive impact on student engagement in the learning process. Students become more active and motivated because they are directly involved in the learning activities [24], [44]. This interactive learning environment encourages students to be more confident in expressing their opinions and asking questions. This active involvement is a crucial factor in improving the quality of learning. With increased student participation, the learning process becomes more dynamic and less monotonous.

However, the effectiveness of inquiry-based learning is greatly influenced by the teacher's readiness to design and implement the lesson. Teachers are required to be able to develop systematic learning scenarios and provide adequate learning resources [45], [46]. Furthermore, time and classroom management are also challenges in implementing this approach. If not well-designed, the inquiry process can become unfocused. Therefore, teacher competence is a key factor in the successful implementation of inquiry-based learning.

On the other hand, the characteristics of the materials also influence the success of inquiry-based learning. The colloidal materials used in this study are related to everyday phenomena, making them easier to explore through inquiry activities [47], [48]. This allows students to connect concepts to real-life experiences. These connections help students build a more contextual understanding. Therefore, selecting appropriate materials is a crucial aspect in implementing inquiry-based learning.

Overall, the results of this study reinforce the view that inquiry-based learning is an effective strategy for improving students' conceptual understanding. This approach focuses not only on the final outcome but also on the learning process itself. Through active engagement, the development of thinking skills, and contextualized learning, students can develop a more comprehensive understanding of concepts [49], [50]. Therefore, inquiry-based learning can be used as an alternative, innovative learning strategy in chemistry education.

This research has a positive impact on chemistry classroom teaching practices. The results can serve as a reference for teachers in selecting more effective learning strategies to improve students' conceptual understanding. The implementation of inquiry-based learning also encourages a paradigm shift from teacher-centered to student-centered learning. Furthermore, this research can serve as a basis for the development of more innovative learning models in the future. Thus, this research contributes to efforts to improve the quality of education, particularly in chemistry learning.

However, this study has several limitations that require consideration. The research design used was a weak experiment without a control group, so comparisons of the results could not fully isolate the effects of the treatment. The limited sample size in one class also limits the generalizability of the research results to a broader population. Furthermore, this study focused only on one topic, colloids, so it may not reflect its effectiveness on other chemistry topics. Other factors such as classroom conditions, student readiness, and teacher skills in implementing inquiry learning may also influence the research results. Therefore, future research is recommended to use a more robust design and broader scope.

4. CONCLUSION

Based on the research results, it can be concluded that inquiry-based chemistry learning has an impact on students' conceptual understanding. This is evidenced by the calculated t value of 4.84, which is greater than the t table value of 2.68. Thus, the statistical test results indicate a significant effect of the application of inquiry-based learning on students' conceptual understanding. Future research is recommended to employ a more robust experimental design, such as involving a control group, and a larger sample size to ensure more generalizable results. Furthermore, the study could be expanded to include various chemistry materials and educational levels to assess the consistency of the effectiveness of inquiry-based learning.

ACKNOWLEDGEMENTS

The author would like to thank all parties who have helped and supported the implementation of this research, both directly and indirectly, so that this research can be completed well.

AUTHOR CONTRIBUTIONS

Conceptualization, K. and D.; Methodology, K.; Software, K.; Validation, K. and D.; Formal Analysis, K.; Investigation, K.; Resources, K.; Data Curation, K.; Writing – Original Draft Preparation, K.; Writing – Review & Editing, K. and D.; Visualization, K.; Supervision, D.; Project Administration, K.; Funding Acquisition, D.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

Not applicable.

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