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Exploring The Impact of Guided Inquiry Learning with a Scientific Approach on Mathematical Conceptual Understanding

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Abstract

This research explores the impact of Guided Inquiry Learning-oriented learning with a scientific approach on understanding mathematical concepts of PGMI UIN Fatmawati Sukarno Bengkulu students. The research design uses an experimental method with an experimental group and a control group. The results of the analysis show that students who were taught using Guided Inquiry Learning-oriented learning experienced a significant increase in understanding mathematical concepts compared to learning without a Guided Inquiry Learning orientation, even though both used a scientific approach. A significant value of less than 0.05 in a statistical test indicates that the difference can be considered statistically significant. However, the results of further analysis showed that there was no significant difference in increasing understanding of mathematical concepts between classes that used the Scientific Approach and the control group in two particular classes (Class=2 and Class=3). A P-value greater than 0.05 in statistical analysis indicates that the results are not statistically significant. Thus, although there was a significant increase in understanding of mathematical concepts in the group that implemented Guided Inquiry Learning-oriented learning, this research also showed that there was no significant difference in this increase between this group and the control group in two particular classes. These results provide further understanding about the effectiveness of certain learning methods in improving students' understanding of mathematical concepts

INTRODUCTION

The mathematics education provided at the tertiary level, particularly in the Pendidikan Guru Madrasah Islam (PGMI) program at UIN Fatmawati Sukarno Bengkulu, plays a crucial role in developing students' abilities to grasp mathematical concepts. A solid understanding of these concepts is fundamental for effectively delivering mathematical material and helping

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students to master the content. This comprehension of mathematical concepts encompasses a deep knowledge of the foundational ideas within mathematical algorithms, requires the selection and application of this understanding through students' active participation, and includes cognitive aspects, alignment of meaning, and recognition of mathematics as a human endeavor, with the ultimate goal of efficiently applying these concepts to solve mathematical problems. [1]–[3].

Students of the PGMI program at UIN Fatmawati Sukarno Bengkulu, as future elementary school teachers, must possess a strong grasp of mathematical concepts to serve as a foundational bridge in developing their students' mathematical understanding. Enhancing the quality of mathematics education at the tertiary level is crucial, and selecting the appropriate teaching approach can significantly improve students' comprehension of mathematical concepts.

The learning approach plays a vital role in shaping students' understanding of mathematical concepts. Consequently, this research seeks to assess the impact of Guided Inquiry Learning in mathematics, combined with a scientific approach, on the ability of PGMI students at UIN Fatmawati Sukarno Bengkulu to comprehend mathematical concepts. This study aims to uncover innovative solutions that can enhance the effectiveness of mathematics education at the tertiary level, particularly within the PGMI program at UIN Fatmawati Sukarno Bengkulu.

This research is backed by several prior studies that highlight its relevance and urgency. These studies emphasize the critical importance of developing a deep understanding of mathematical concepts as the primary foundation in the learning process. [4], [5]. Other research underscores the significance of understanding psychological factors, problem-solving strategies, the role of teachers, mathematical literacy, and the role of representation in developing students' mathematical concepts as the essential foundation for effective teaching and learning in mathematics. [6]–[12]

Enhancing students' understanding of mathematical concepts can be accomplished through innovative teaching methods, such as the implementation of guided inquiry learning. This approach positively impacts students' ability to grasp mathematical concepts, thereby enriching their overall learning experience in mathematics. [13], [13]–[17].

Another innovation in mathematics education involves integrating a scientific approach into the learning process. The scientific approach in teaching mathematics has consistently proven effective in enhancing students' understanding of concepts and mathematical abilities. This approach supports various methods, including problem-solving strategies, scientific-based constructivist learning, and innovative techniques like the What-If-Not strategy. Additionally, it contributes positively to the development of higher-order thinking skills, such as communication, creativity, and mathematical reasoning. [18], [19], [28], [20]–[27]. This approach not only fosters an engaging and easily understandable learning environment but also encourages active student participation, enhances learning independence, and positively influences mathematics learning outcomes.

By exploring these various perspectives, this research aims to make a significant contribution to our understanding of the impact of Guided Inquiry Learning (GIL) in mathematics, combined with a scientific approach, on students' comprehension of

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mathematical concepts. The choice of learning approach is a critical factor in shaping students' understanding of these concepts. Therefore, this study seeks to assess the effectiveness of Guided Inquiry Learning with a scientific approach on the mathematical concept mastery of PGMI students at UIN Fatmawati Sukarno Bengkulu. The goal is to discover innovative solutions that can enhance the effectiveness of mathematics education at the tertiary level, particularly within the context of the PGMI program at UIN Fatmawati Sukarno Bengkulu..

METHOD

This research employs an experimental design featuring both pretest and posttest evaluations for both the experimental and control classes. The study involves four classes, all of which will undergo a pretest before any treatment is administered. Following the treatment, these four classes will also complete a posttest. Both the pretest and posttest will utilize the same instrument to ensure consistency. Based on the research variables previously outlined, the design of this study can be illustrated as follows:

Table 1. Research Design Research on the Ability to Understand Mathematical Concepts

	Guided Inquiry Learning (GI)	Non Guided Inquiry Learning (ngI)
Saintific (S)	S, GI	S, nGI
Non Saintific (NS) (Conventional)	NS, GI	NS, nGI

In Experiment 1, students were exposed to a scientific approach that encouraged guided inquiry, allowing them to actively explore mathematical concepts. Experiment 2 also used a scientific approach but without the specific focus on guided inquiry. Experiment 3 employed a traditional teaching method with a guided inquiry focus, while the control group used a conventional, non-guided inquiry approach. By comparing the outcomes of these experiments, researchers could investigate the effectiveness of different teaching methods and the impact of guided inquiry on student learning and understanding of mathematical concepts.

Table 2. Number of Research Samples

Class	Experiment 1	Experiment 2	Experiment 3	Control
Many Students	17	18	18	18

Three distinct treatments were applied in this research. The first treatment compared guided inquiry learning to non-guided inquiry learning, both of which utilized a scientific approach. The second treatment contrasted a scientific approach with conventional learning, both within the context of guided inquiry learning. The third treatment examined the difference between guided inquiry learning and non-guided inquiry learning, both using conventional learning models. These treatments allowed researchers to investigate the impact of various teaching methods and the role of guided inquiry in student learning.

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RESULTS AND DISCUSSION

For data analysis, use Anacova with the help of SPSS version 16 software. With the results of the normality test using Shapiro Wilk and Kolmogorov-Smirnov, the following data analysis results were obtained:

Table 3. Tests of Normality

	Shapiro-Wilk		
	Statistics	df	Sig.
Experiment 1 Pretest	0,896	17	0,058
Experiment Posttest 1	0,906	17	0,087
Experiment 2 Pretest	0,936	17	0,277
Experiment Posttest 2	0,933	17	0,245
Experiment 3 Pretest	0,896	17	0,057
Experiment Posttest 3	0,966	17	0,753
Experiment 4 Pretest	0,934	17	0,252
Experiment Posttest 4	0,896	17	0,058

Shapiro Wilk normality tests that the sig value for both is more than 0.05, then the data has a normal distribution.

The homogeneity test was carried out using the Levene test

Table 4 Treatment Homogeneity Test

Levene's Test of Equality of Error Variances [a]

Dependent Variable: Posttest

	F	df1	df2	Sig.
Posttest 1	0,311	1	33	0,581
Posttest 2	0,211	1	33	0,649

The three treatments show a sig value of more than 0.05 with the assumption that the data from treatment 1 to treatment 3 has homogeneous data.

Data processing results

Table 5. Levene's Test of Equality of Error Variances [a]

Dependent Variable: Posttest 1

F	df1	df2	Sig.
1,353	3	67	0,265

Homogeneity after controlling for students' initial abilities in understanding mathematical concepts still shows homogeneous data.

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Table 6. Tests of Between-Subjects Effects

Dependent Variable: Posttest 1

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2461.581 [a]	7	351,654	24,082	0,000	,728
Intercept	8065.694	1	8065.694	552,344	0,000	,898
Class	155,243	3	51,748	3,544	0,019	.144
Pretest1	265,715	1	265,715	18,196	0,000	,224
Class * Pretest1	83,352	3	27,784	1,903	0,138	,083
Error	919968	63	14,603			
Total	427890,000	71				
Corrected Total	3381,549	70				

Table 7 Parameter Estimates

Dependent Variable: Posttest 1

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval		Partial Eta Squared
					Lower Bound	Upper Bound	
Intercept	59,846	5,542	10,798	0,000	48,771	70,921	0,649
[Class=1]	19,617	7,503	2,614	0,011	4,623	34,612	0,098
[Class=2]	-4,513	8,843	-.510	,612	-22,185	13,159	0,004
[Grade=3]	8,186	7,200	1,137	,260	-6,202	22,574	0,020
[Grade=4]	0 [a]	.	.	.	.	.	.
Pretest1	,169	,095	1,776	0,081	-.021	,360	0,048
[Class=1] * Pretest1	-.082	.126	-.646	0,521	-.334	,171	0,007
[Class=2] * Pretest1	,246	,150	1,636	0,107	-.054	,545	0,041
[Grade=3] * Pretest1	-.039	.122	-.317	0,752	-.284	,206	0,002
[Class=4] * Pretest1	0 [a]	.	.	.	.	.	.

Table 8 Pairwise Comparisons

Dependent Variable: Posttest 1

(i) Class	(J) Class	Mean Difference (IJ)	Std. Error	Sig. [a]	95% Confidence Interval for Difference [a]	
					Lower Bound	Upper Bound
Experiment 1	Experiment 2	4,934 *	1,297	0,000	2,343	7,525
	Experiment 3	8,918 *	1,296	0,000	6,327	11,508
	Control	14,827 *	1,302	0,000	12,225	17,429
Experiment 2	Experiment 1	-4,934 *	1,297	0,000	-7,525	-2,343
	Experiment 3	3,984 *	1,274	0,003	1,438	6,530
	Control	9,893 *	1,280	0,000	7,335	12,451
Experiment 3	Experiment 1	-8,918 *	1,296	0,000	-11,508	-6,327
	Experiment 2	-3,984 *	1,274	0,003	-6,530	-1,438
	Control	5,909 *	1,280	0,000	3,352	8,466
Control	Experiment 1	-14,827 *	1,302	0,000	-17,429	-12,225
	Experiment 2	-9,893 *	1,280	0,000	-12,451	-7,335
	Experiment 3	-5,909 *	1,280	0,000	-8,466	-3,352

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Based on the parameter estimation results you provided, we can draw several conclusions:

1. Intercept:
   The intercept value is 59,846, with a standard error of 5,542. This shows that the average mathematical ability in the control group (Grade=4) is around 59,846 with a 95% confidence interval between 48,771 and 70,921. The Partial Eta Squared value of 0.649 indicates that the intercept has a significant contribution in explaining the variability of mathematical abilities.
2. Influence of Class Variables (Class=1, Class=2, Class=3) and Pretest1:
   - Class=1 has a significant influence on students' mathematical abilities. The B value is 19.617 with a standard error of 7.503 and a p-value of 0.011. This means that the group that used a Scientific Approach Oriented to Guided Inquiry Learning (Class=1) had an average increase of 19,617 in mathematics ability compared to the control group.
   - Class=2 and Class=3 do not have a significant influence on students' mathematical abilities. The B value for Class=2 is -4.513 with a p-value of 0.612, and for Class=3 it is 8.186 with a p-value of 0.260.
3. Influence of Pretest Variables1:
   The Pretest1 variable has an influence that approaches the significance level. The B value is 0.169 with a standard error of 0.095 and a p-value of 0.081. This shows that students' initial mathematics abilities (pretest1) have a positive impact, although not significantly, on their mathematics abilities after intervention (posttest1).
4. Effect of Interaction between Class and Pretest1:
   The interaction between Class and Pretest1 (Class * Pretest1) does not have a significant effect on students' mathematical abilities. All B values for this interaction (Class=1 * Pretest1, Class=2 * Pretest1, Class=3 * Pretest1, Class=4 * Pretest1) are not significant (p-value > 0.05).

Overall, the analysis indicates that the group utilizing the Scientific Approach Oriented to Guided Inquiry Learning (Grade=1) experienced a significant improvement in their ability to understand mathematical concepts compared to the control group. However, no significant difference was observed in mathematical abilities between the group using the Scientific approach (Grades 2 and 3) and the control group (Grade 4). The Pretest1 variable, which reflects students' initial understanding of mathematical concepts, showed a positive, though not statistically significant, effect on their mathematics abilities after the intervention. Additionally, the interaction between Class and Pretest1 did not significantly impact students' comprehension of mathematical concepts.

Scientific understanding also involves a similar process of recognizing and appropriating the meaning of scientific concepts in the context of scientific investigation and discovery. Both understanding mathematical concepts and scientific understanding require recognition of characteristic properties and relationships with other entities, as well as the use of symbolic notation to represent situations and solutions [2]. Therefore, the process of understanding mathematical concepts has similarities with the process of understanding scientific concepts.

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Other research finds that a positive attitude towards mathematics can improve student performance in mathematics, while higher conceptual understanding can improve student performance in mathematics [1].

From the results of the analysis provided, it can be concluded that the class that uses a Scientific Approach Oriented to Guided Inquiry Learning (Class=1) is a class that is better at improving students' mathematical abilities compared to the control group (Class=4).

Several factors that influence the ability to understand mathematical concepts include the learning approach used, the teacher's ability to determine appropriate learning strategies, the level of difficulty and abstraction of mathematical concepts, and students' ability to understand and interpret the material being studied. Apart from that, the learning approach used can also influence students' ability to understand mathematical concepts [29].

There is a connection between understanding mathematical concepts and scientific understanding, as well as scientific discoveries and investigations. Grasping mathematical concepts entails recognizing the systemic complexity of an object's meaning, highlighting the dynamic, progressive, and non-linear nature of the subject's process of assimilation. This process includes acknowledging the various domains of experience and institutional contexts in which individuals engage. [2].

This can be seen from the estimated parameter value (B) for Class=1, which has a positive and significant value (p-value = 0.011). The B value of 19,617 indicates that the group that used the Scientific Approach Oriented to Guided Inquiry Learning (Class=1) experienced an average increase of 19,617 in the ability to understand mathematical concepts compared to the control group that used the Conventional Learning Model (Class=4). The influence of the guided inquiry learning model on understanding mathematical concepts has been researched and proven to be effective in increasing students' understanding of mathematical concepts [30]. In the context of mathematics, understanding mathematical concepts involves students' ability to formulate solving strategies, apply simple calculations, use symbols to present concepts, and change one form to another without changing the meaning of the concept [3].

Meanwhile, the estimated parameter values for Class=2 and Class=3 are not significant (p-value > 0.05), so there is no significant difference in the ability to understand mathematical concepts between these two groups and the control group (Class=4). There are other factors that influence the ability to understand mathematical concepts. Factors that influence mathematical concept abilities include students' attitudes towards mathematics, students' conceptual understanding of mathematics, and student demographic profiles such as gender, parental education, and family income [1].

Thus, based on the results of the analysis, Class=1 (Scientific Approach Oriented to Guided Inquiry Learning) is a class that is better at improving students' mathematical abilities in understanding mathematical concepts compared to the control group (Conventional Learning Model). In other research, it is stated that guided inquiry learning helps students to better understand mathematical concepts through an active approach based on exploration and discovery [26], [30]–[32].

The guided inquiry learning model is more effective in improving students' understanding of mathematical concepts than the conventional learning model. This is because guided inquiry learning provides opportunities for students to be actively involved in the learning process,

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starting from formulating problems, collecting data, analyzing data, and drawing conclusions.

The scientific approach in learning mathematics emphasizes understanding concepts and applying mathematical knowledge in real situations. By using a scientific approach, students are invited to be actively involved in the learning process, make choices, and apply their understanding of mathematical concepts. This is in accordance with the concept of understanding mathematical concepts which involves a thorough understanding of the basic concepts behind algorithms carried out in mathematics [1].

The scientific approach in mathematics learning emphasizes on understanding concepts and applying mathematical knowledge in real situations. This is in line with the concept of understanding mathematical concepts which involves a thorough understanding of the basic concepts behind the algorithms performed in mathematics. By using the scientific approach, students are invited to be actively involved in the learning process, starting from observing, questioning, gathering information, associating / analyzing, and communicating. These activities can help students to understand mathematical concepts deeply and apply them in real situations.

Based on the data analysis carried out, it can be stated that guided inquiry learning mathematics with a scientific approach has an impact on the ability to understand mathematical concepts. This is in line with research which states that the application of Guided Inquiry Learning mathematics with a scientific approach can improve students' critical thinking skills in mathematics. This can have an impact on students' ability to understand mathematical concepts. It has been proven that the application of certain learning methods can improve and influence their understanding of mathematical concepts [33].

An increase in critical thinking skills can positively affect students' ability to understand mathematical concepts, as these skills enable a deeper and more comprehensive grasp of the material. Consequently, employing Guided Inquiry Learning in mathematics, combined with a scientific approach, can be an effective method for enhancing students' understanding of mathematical concepts..

The research, while providing valuable insights, has several limitations. The small sample size and specific geographic and demographic context may limit the generalizability of the findings. The study's internal validity could be affected by uncontrolled confounding variables, and the measurement instruments used may not be fully validated. Additionally, the research was conducted in a particular school setting and may not be applicable to all educational contexts. The study established a correlation between critical thinking skills and mathematical concept understanding but did not definitively prove a causal relationship. Lastly, guided inquiry learning may be challenging to implement effectively in all classrooms, and its effectiveness may vary depending on individual student characteristics. Future research should address these limitations by using larger samples, employing rigorous research designs, using validated instruments, and considering the impact of contextual factors.

CONCLUSION

The findings reveal that mathematics learning using Guided Inquiry Learning combined with a scientific approach significantly enhanced the understanding of mathematical concepts among PGMI UIN Fatmawati Sukarno Bengkulu students compared to the control group, which showed an average increase of 19,617. In contrast, the groups employing only a scientific

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approach or solely Guided Inquiry Learning did not demonstrate significant improvements. The Pretest1 variable, reflecting students' initial abilities, approached significance, but the interaction between Class and Pretest1 did not significantly affect students' mathematical abilities, suggesting other influencing factors.

The Scientific Approach Oriented to Guided Inquiry Learning has proven effective in improving students' understanding of mathematical concepts, aligning with the close relationship between concept comprehension and the scientific approach. Practically, lecturers should consider this method as a valuable learning strategy, while also accounting for factors such as teaching methods, teacher competence, the difficulty of mathematical concepts, and students' grasp of the material. Thus, active learning strategies like Guided Inquiry Learning with a scientific approach can serve as an effective alternative for enhancing students' understanding of mathematical concepts.

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