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The Effect of Motivation and Interaction Effects on Improving Mathematical Comprehension Skills through Problem and Inquiry-Based Learning

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Abstract

This study investigates the influence of motivation levels and interaction effects on students' Mathematical Comprehension Ability (KPM) while utilizing Problem-Based Learning (PBL) and Inquiry-Based Learning (IBL). Employing a quasi-experimental with the 3x2 factorial design, the research was conducted with fourth-grade students in Ciamis Regency, West Java. The findings indicated that the average KPM increase for students using PBL was 53%, which is considered moderate, whereas for IBL, it was 29%, which is categorized as low. Significantly, there were variations in learning effects between PBL and IBL ($p < 0.001$), with PBL demonstrating a more pronounced impact on KPM improvement. However, the influence of motivation level on KPM improvement was deemed insignificant ($p = 0.192$), as was the interaction effect between learning methods and motivation level on KPM improvement ($p = 0.057$). In conclusion, the study suggests that PBL is more effective than IBL in enhancing students' KPM. At the same time, motivation level does not significantly influence KPM improvement, and there is no interaction effect between the type of learning method and motivation level on KPM improvement.

Keywords: Mathematical Comprehension Ability, Motivation, PBL and IBL.

Introduction

Mathematics plays a crucial role in society and technological advancement. Its applications in everyday life are widely recognized, ranging from simple arithmetic to complex calculations in various fields such as construction, economic systems, and markets. The Merdeka curriculum outlined in Permendikbudristek No. 12 of

2024 emphasizes the significance of studying mathematics in developing moral values, including freedom, accuracy, systematicity, rationality, and creativity. Therefore, proficiency in mathematics is essential for success in the modern world and contributes to an improved quality of life.

In many countries, including Indonesia, prioritizing conceptual understanding in mathematics education has gained significant attention (NCTM, 2000; KEMDIKBUD, 2018). Nevertheless, implementing mathematics education that emphasizes conceptual understanding encounters various challenges (Yusuf, 2022; Purwanti & Mujiasih, 2021). Many students rely on rote memorization and procedural application in mathematics, lacking a deeper understanding of the underlying rationale (Janine et al., 2022). This highlights the importance of solving mathematical problems accurately and comprehending the procedures' principles and methodologies.

The lack of conceptual understanding hinders students' ability to solve mathematical problems effectively. According to Surif, Ibrahim, and Mochtar (2012), a firm grasp of conceptual and procedural aspects directly influences mathematical problem-solving skills. Wahyudin (in Nasution, 2013) suggested that students' struggles with mathematics stem from their difficulty grasping the fundamental principles of mathematics, such as axioms, definitions, rules, and theorems. Moreover, traditional learning methods, which are commonly used, are not very effective in improving students' conceptual understanding. These methods often prioritize rote memorization and the application of mathematical procedures over developing a deep understanding of concepts (Masooma et al., 2019). As a result, students find it challenging to connect the mathematical concepts they learn with real-world problems they encounter daily (Kai et al., 2021).

Prior studies have shown that innovative learning approaches, such as problem-based learning (PBL) and inquiry-based learning (IBL), effectively enhance students' understanding of mathematics. PBL utilizes problems to acquire new knowledge (Ibrahim, 2000) and enhances students' critical thinking skills through a structured group process (Tan in Rusman, 2016). Research by Munawaroh (2022) discovered that the PBL model significantly impacts student motivation, achievement, and interest in learning. IBL involves students actively learning to explore concepts (Kunandar & Sanjaya in Shoimin, 2018). Gulo (in Al-Tabany, 2014) asserts that IBL enhances students' logical, systematic, and analytical search skills. While evidence supports the effectiveness of PBL and IBL, previous research has also identified some drawbacks. Firstly, implementing PBL and IBL often demands a more significant time commitment and more extensive preparation from teachers (Shumaila & Ali, 2022). Secondly, not all teachers possess the necessary skills to effectively employ these methods (Nanxi & Dong, 2023). Lastly, in certain instances, students may encounter challenges adapting to a more independent learning approach and may require increased support from the teacher (Honda et al., 2023).

Previous research has often overlooked the crucial interaction between innovative learning methods and students' motivation levels (Istvan, 2022). While PBL and IBL have shown effectiveness, studies often fail to account for how variations in student motivation may impact learning outcomes (Sari & Sutriyani, 2023). Many studies also narrowly focus on the effectiveness of either PBL or IBL without considering the interplay between the two methods. Additionally, contextual factors such as students' socioeconomic backgrounds and teachers' abilities to implement innovative learning methods are frequently neglected in research, potentially leading to misrepresentation of findings and invalid generalizations about the applicability of results in diverse educational settings.

The preceding background and literature review indicate that this study seeks to comprehensively analyze two main areas: the impact of motivation levels on enhancing students' mathematics comprehension skills and the interaction effect between learning methods (PBL and IBL) and students' learning. The study will investigate the influence of motivation on students' mathematics comprehension skills, the differential effects of PBL and IBL models on students' mathematics comprehension skills, and the combined influence of learning methods and students' motivation on their mathematics comprehension skills. As a result, the findings of this research are expected to contribute to the development of effective learning models for improving students' mathematical comprehension abilities. Additionally, the importance of motivation in the learning process is anticipated to be emphasized.

Methods

This research study involved fourth-grade students from an elementary school in Ciamis Regency, West Java. The study was conducted from February to March 2023 and used purposive sampling to select 28 pupils, with 16 students in the experimental group and 12 in the control group. Data collection included quantitative data on students' mathematical understanding ability, gathered through tests and questionnaires. The test was utilized to collect data on the pupils' mathematical abilities. At the same time, the questionnaire was used to assess the impact of motivation and the interaction effect of PBL (Problem-Based Learning) and IBL (Inquiry-Based Learning) approaches.

This study utilized experimental research with a quasi-experimental design, explicitly employing a one-group pretest-posttest design. The data analysis consisted of a one-way ANOVA with a 3 x 2 factorial design. The details of the 3 x 2 factorial design are presented in Table 2.1 below.

Table 1

Factorial Design 3 x 2

		Learning Model	
		Problem-Based Learning (PBL) (X_1)	Inquiry-Based Learning (IBL) (X_2)
Learning Motivation Level	High (Y_1)	X_1, Y_1	X_2, Y_1
	Medium (Y_2)	X_1, Y_2	X_2, Y_2
	Low (Y_3)	X_1, Y_3	X_2, Y_3

In a 3 x 2 factorial design, the researcher implemented Problem-Based Learning (PBL) in the experimental class and Inquiry-Based Learning (IBL) in the control class. Problem-based learning involves identifying and articulating problems, gathering information, formulating hypotheses, conducting investigations, generating and evaluating alternative solutions, and testing outcomes. Inquiry-based learning includes exploration, autonomous learning, evaluation, consolidation, and instructor guidance.

The lesson plan (RPP) outlines the teaching methods used in the experimental and control groups, employing the PBL and IBL models (Hake, 2002). The results were evaluated based on the increase in students' Mathematical Comprehension Ability (KPM) using the n-gain formula and interpreted with score categories classified as high ($g > 0.7$), medium ($0.3 < g < 0.7$), and low ($g < 0.3$) (Meltzer, 2002). The normalized n-gain formula was utilized to assess the enhancement in students' mathematical proficiency and learning motivation levels.

Results

This study analyzed quantitative data from pretest, posttest, and n-gain scores related to students' Mathematical Comprehension Ability (KPM). The student average for Mathematical Comprehension Ability (KPM) using Problem-Based Learning (PBL) and Inquiry-Based Learning (IBL) is presented in Table 1.

Table 1

Pretest, Posttest, and N-gain Scores of Mathematical Comprehension Ability Improvement based on Problem-Based Learning and Inquiry-Based Learning

Problem-Based Learning					**Inquiry-Based Learning**				
No	**Student**	**Pretest**	**Postest**	**N-gain**	**No**	**Student**	**Pretest**	**Postest**	**N-gain**
1	S1	50	60	0,20	1	S1	40	80	0,43
2	S2	30	70	0,57	2	S2	25	65	0,20
3	S3	60	80	0,50	3	S3	35	65	0,00
4	S4	30	70	0,57	4	S4	10	50	0,43
5	S5	40	75	0,58	5	S5	35	65	0,29
5	S5	40	75	0,58	6	S6	10	45	0,20

6	S6	30	75	0,64	7	S7	30	55	0,25
7	S7	50	75	0,50	8	S8	40	70	0,20
8	S8	60	70	0,25	9	S9	55	90	0,25
9	S9	70	80	0,33	10	S10	30	75	0,60
10	S10	40	75	0,58	11	S11	30	60	0,40
11	S11	30	85	0,79	12	S12	30	70	0,20
12	S12	80	90	0,50					
13	S13	60	90	0,75					
14	S14	60	85	0,63					
15	S15	70	80	0,33					
16	S16	60	85	0,63					

Based on the data in Table 1, students who participated in problem-based learning demonstrated an average mathematical growth understanding ability of 0.53 (53%), while those engaged in inquiry-based learning showed an average enhancement of 0.29 (29%). Consequently, the average score for problem-based learning surpassed that of inquiry-based learning. The improvement criteria for problem-based learning fall within the intermediate category, whereas inquiry-based learning falls within the low category.

According to the standard deviation score, the range of scores for enhancing mathematical understanding among students using problem-based learning is 0.17, while the range for enhancing mathematical understanding among students using inquiry-based learning is 0.16. This indicates that the distribution of scores for improving mathematical understanding among students using problem-based learning is more varied than those using inquiry-based learning.

The skewness value for the improvement scores in students' understanding of mathematics was -0.599 for those who underwent problem-based learning and 0.322 for those who underwent inquiry-based learning. These results suggest that the distribution of scores for students' mathematical understanding improvement with problem-based learning is negatively skewed, indicating that most scores are concentrated at the higher end. Conversely, the distribution of scores for students' mathematical understanding improvement with inquiry-based learning is positively skewed, suggesting that most scores are concentrated at the lower end. The descriptive analysis results for students' proficiency in mathematics improvement based on learning and motivation level are shown in Table 2 below.

Table 2

Descriptive analysis results regarding kids' proficiency in mathematics improvement based on learning and learning motivation levels

Learning Model	Learning Motivation	Mean	Std. Deviation	N
Problem-Based Learning (PBL)	High	0,60	0,19	5
	Medium	0,57	0,04	6
	Low	0,40	0,20	5

	Total	0,53	0,17	16
Inquiry-Based Learning (IBL)	High	0,36	0,18	4
	Medium	0,16	0,11	4
	Low	0,34	0,11	4
	Total	0,29	0,16	12
Total	High (PBL and IBL)	0,49	0,21	9
	Medium (PBL and IBL)	0,40	0,22	10
	Low (PBL and IBL)	0,37	0,16	9
	Total	0,42	0,20	28

Based on Table 2, the results of descriptive statistical analysis can be explained that the group of students who have a high level of student learning motivation, the average score (mean) of the increase in Mathematical Comprehension Ability (KPM) of students who learn with the Problem-Based Learning model is 0.60. For students who acquire knowledge using the Inquiry-Based Learning model, the average score (mean) increase is 0.36. Then, the group of students with a moderate level of learning motivation is the average score (mean) of the increase in Mathematical Comprehension Ability (KPM) of students who learn with the Problem-Based Learning model of 0.57.

Rata-rata peningkatan skor untuk siswa yang menggunakan model Pembelajaran Berbasis Inkuiri adalah 0,16. Selain itu, untuk siswa dengan motivasi belajar rendah, rata-rata peningkatan skor Kemampuan Pemahaman Matematis (KPM) dengan menggunakan model Pembelajaran Berbasis Masalah adalah 0,40. Rata-rata skor yang diperoleh siswa yang menggunakan model Pembelajaran Berbasis Inkuiri adalah sebesar 0,34.

Table 3

Test of Between-Subjects Effects - General Linear Model on improving students' mathematical understanding ability

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	.611[a]	5	.122	5.632	.002
Intercept	4.499	1	4.499	207.480	<.001
Learning	.382	1	.382	17.599	<.001

Motivation	.077	2	.039	1.780	.192
Learning* Motivation	.142	2	.071	3.266	.057
Error	.477	22	.022		
Total	6.128	28			
Corrected Total	1.088	27			

a. R Squared = .561 (Adjusted R Squared = .462)

Table 3 shows several notes: the significance value in learning <.001, which is less than 0.05 (α). These results explain differences in the influence of problem-based and inquiry-based learning on improving students' mathematical understanding abilities because the average mathematical understanding ability of those learning with problem-based learning is 0.53, which is greater than that of those learning with inquiry-based learning, namely 0.29, problem-based learning has a higher effect than inquiry-based learning, towards increasing students' mathematical understanding abilities.

The significance value for motivation is 0.192, greater than 0.05 (α). This means that there is no significant difference in the impact of different levels of learning motivation on students' math comprehension ability. Since the results showed no difference in the level of learning motivation in enhancing students' math understanding, the post hoc test was used to calculate the increase in math understanding based on the level of motivation. The results of the post hoc test can be seen in Table 4.

Table 4

Conducting a post hoc test to evaluate the impact of boosting students' mathematical comprehension on their levels of learning motivation

					95% Confidence Interval	
(I) Level Motivation	(J) Level Motivation	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
High	Medium	.0854	.06766	.430	-.0845	.2554
	Low	.1233	.06942	.201	-.0510	.2977
Medium	High	-.0854	.06766	.430	-.2554	.0845
	Low	.0379	.06766	.842	-.1321	.2079
Low	High	-.1233	.06942	.201	-.2977	.0510
	Medium	-.0379	.06766	.842	-.2079	.1321

It is derived from recorded averages.
The error term is the mean square of the (error.) = .022.

Table 4 indicates that the difference in the influence of the level of learning motivation on increasing students' mathematical understanding abilities between students who have high and moderate levels of motivation is that the significance level is 0.430, where this value is more significant than 0.05 (α). This shows no significant difference between the mean score of increasing students' mathematical understanding abilities between students with a high level of learning motivation and students with a moderate level of learning motivation. Then, the difference in the influence of the level of learning motivation on increasing students' mathematical understanding abilities between students with high and low motivation levels shows that the significance level is 0.201, where this value is more significant than 0.05 (α).

The analysis shows no significant difference in the average scores of students' mathematical understanding abilities between those with high and low levels of learning motivation. Additionally, the difference in the impact of learning motivation on students' mathematical understanding abilities between those with medium and low motivation levels is not statistically significant, with a significance level of 0.842, greater than 0.05 (α). This suggests that students' motivation levels do not significantly affect their mathematical understanding abilities.

Furthermore, the results indicate that the significance value between motivation levels is 0.057, which is greater than 0.05 (α), indicating no interaction effect between the learning model and the level of learning motivation on students' mathematical understanding abilities. The R-squared value of 0.561 also shows that the relationship between the learning model and the level of learning motivation in enhancing students' mathematical understanding abilities is not statistically significant.

Discussion

This study demonstrated that students employing Problem-Based Learning (PBL) experienced a 53% increase in Mathematical Comprehension Ability (KPM), compared to a 29% increase for those using Inquiry-Based Learning (IBL). PBL was more effective in enhancing mathematical understanding, with a broader spread of score distributions indicating more significant variability in student outcomes. Additionally, PBL students' improvement scores were generally higher, as evidenced by a negative skew in the data distribution, whereas IBL students' scores were more commonly lower, showing a positive skew. Overall, both PBL and IBL were beneficial in improving students' mathematical understanding.

The significance result of learning 0.007 is smaller than 0.05, so there is a disparity in the impact of learning between PBL and IBL on increasing students'

KPM. The difference in the effect of the learning implementation of the Problem-Based Learning (PBL) model and the Enquiry Based Learning (IBL) model on improving students' Mathematical Comprehension Ability (KPM) is accepted because the learning of 0.007 is smaller than the value of α = 0.05. The results of this study are in line with Munawaroh et al. (2022) that the PBL model has a significant effect on student motivation, interest, and learning achievement, and the characteristics of PBL with a variety of learning strategies and emphasizes problem-solving efforts to improve students' average ability.

The significance of the motivation level of 0.097 is more significant than 0.05, so there is no difference in the effect of motivation level on increasing students' KPM. There is no discernible distinction in the impact of motivation level on increasing students' Mathematical Comprehension Ability (KPM). This implies that pupils may not be inclined to comprehend and solve mathematical problems when learning. This aligns with Indriani's (2016) assertion that students' motivation also impacts their achievement in mathematics learning. If students are not motivated to learn, then forever, students will not be interested in math lessons, and learning becomes meaningless. Student mathematics learning achievement is also related to learning motivation; interest and satisfaction in learning will make knowledge more meaningful (Indriani, 2016; Nunaki et al., 2019). Therefore, the motivation to learn mathematics is influenced by the interaction effect; this follows the explanation of Lestari (2020), which reveals that inspiration to learn is closely related to motives, which include external and internal variables that affect a person's desire to learn.

The analysis of the interaction effect between learning and motivation level obtained a value of 0.647, more significant than 0.05, so there is no interaction effect between learning and the level of student learning motivation on improving students' KPM. It can be inferred that there is no significant interaction between the learning process and the level of motivation for student achievement in improving students' mathematical comprehension ability (KPM).

The acquisition of mathematical knowledge appears to be unaffected by students' motivation and interaction. This lack of influence may stem from students' insufficient effort and persistence in comprehending the material. As noted by Priansa (2017), learning motivation encompasses effort, persistence, and direction. Within the classroom, varying levels of motivation, whether high, medium, or low, do not significantly impact students' grasp of mathematical concepts. This could be attributed to external factors that influence each student's motivation. It is essential to identify these external factors and address them in order to enhance students' mathematical comprehension. Furthermore, there seems to be no discernible interaction effect between motivation and learning, possibly due to inadequate motivation, student engagement, and a lack of harmonious relationships between educators and students.

Conclusion

The research findings indicate that problem-based learning (PBL) results in a more substantial enhancement of students' mathematical understanding ability than inquiry-based learning (IBL). Moreover, the influence of PBL on improving students' Mathematical Comprehension Ability (KMS) is statistically significant, with a p-value of less than .001. However, there is no notable disparity in the effect of motivation levels on enhancing students' mathematical comprehension ability.

The findings suggest that the discussed learning model can be used in learning. However, further investigation is necessary to explore alternative learning models that may result in more significant improvements. Despite being classified as medium or low, the PBL model is recommended for classroom learning due to its more significant influence than the IBL model. It is worth noting that motivation levels do not differ significantly across high, medium, and low categories. This lack of significance may be due to various factors affecting student motivation. Identifying and addressing these external factors is crucial to have a noticeable impact on the relationship between motivation levels and improving students' mathematical understanding.

The lack of interaction between motivation and learning may be due to insufficient motivation and student engagement and a lack of harmonious rapport between researchers and students. Therefore, promoting engagement and effective communication between students and researchers is essential to nurture a healthy relationship and facilitate a synergistic interplay between learning and motivation.

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