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The Effectiveness of Problem Based Learning and Project Based Learning on Mathematical Concept Understanding: A Study of Junior High School Students

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Abstract

This study aims to compare the effectiveness of the Problem Based Learning (PBL) and Project Based Learning (PjBL) models on junior high school students' mathematical concept understanding. This research employed a quantitative approach with a quasi-experimental method using a pretest–posttest control group design. The population consisted of seventh-grade students from a junior high school in Yogyakarta, from which two sample groups were selected using purposive sampling based on predetermined characteristics. A concept understanding test was used as the main instrument to measure students' mathematical concept mastery. Data were collected through pretest and posttest assessments and analyzed using a paired sample t-test to determine the improvement within each group and an independent two-sample t-test to compare the effectiveness between the two learning models. The findings indicate a significant increase in students' mathematical concept understanding after the implementation of both PBL and PjBL models. The results also show that although both models are effective in enhancing conceptual understanding, there is no statistically significant difference in effectiveness between PBL and PjBL. These results suggest that both learning models can be used as alternative student-centered instructional approaches to support deeper conceptual understanding in mathematics learning at the junior high school level.

Keywords: *Problem-Based Learning; Project-Based Learning; Mathematical Concept Understanding*

Introduction

Mathematics is a subject that plays an important role in shaping logical and systematic thinking patterns. Mathematics plays an important role in developing these skills, particularly through conceptual understanding (Murtiyasa & Sari, 2022). In the Merdeka Curriculum, mastery of conceptual understanding is a core competency that students are expected to apply mathematical knowledge in everyday situations. Conceptual understanding is the basis for developing higher-order thinking skills such as analysis and problem solving. Understanding mathematical concepts is very important because it allows students to explain the interrelationships between concepts and apply them in problem solving (Cahani et al., 2021). Students who understand concepts well will find it easier to solve mathematical problems, relate concepts between fields of study, and apply them in everyday life. Research shows that conceptual understanding must be built interactively between teachers and students and instilled early on because it is the basis for understanding advanced material (Radiusman, 2020). However, in reality, the ability to understand concepts, which is important in mathematics learning, is not in line with the current state of students' understanding of mathematical concepts.

According to the OECD (2022), the global average mathematics score on PISA in 2022 decreased by about 15 points compared to 2018, indicating that more students have not achieved adequate mathematical conceptual understanding. Several studies show that students often misunderstand concepts and rely more on memorizing formulas (Suendarti & Liberna, 2021; Wuryanti & Sutama, 2022). This indicates the need for more effective learning strategies to foster students' ability to understand the concepts in the material being studied. This condition emphasizes that mathematics learning needs to be directed towards an approach that encourages students to understand concepts deeply through active and meaningful learning experiences. The Problem-Based Learning (PBL) and Project-Based Learning (PjBL) models are relevant alternatives because they place problems and projects at the center of learning activities, encouraging students to think critically, construct knowledge, and apply mathematical concepts in various real-world contexts. Through the PBL syntax, students are trained to identify problems, investigate solutions, and evaluate their thinking processes. Meanwhile, PjBL provides opportunities for students to design and produce products that reflect a more authentic understanding of concepts. Therefore, the use of PBL and PjBL in this study is expected to contribute to improving mathematical concept comprehension while overcoming the tendency of students to memorize formulas without understanding their meaning.

The PBL model consists of several steps, namely: (1) orienting students to the problem; (2) organizing students in learning activities; (3) facilitating independent and group investigations; (4) developing and presenting work results or products; and (5) analyzing and evaluating learning (Mashuri et al., 2019). Meanwhile, the steps of the PjBL model are: (1) determining fundamental questions; (2) designing project plans; (3) setting schedules; (4) implementing projects; (5) presenting project results; (6) assessment and evaluation (Dinda & Sukma, 2021). Several previous studies have tested the effectiveness of the Problem Based Learning (PBL) and Project Based Learning (PjBL) models. The results show that the application of PBL has a positive impact on improving students' conceptual understanding (Rizqi et al., 2020). The use of the Problem-Based Learning (PBL) model has been proven effective in helping students understand the concepts of the material being studied, thereby improving student learning outcomes (Solfiana et al., 2025). The active question and answer activities in Problem-Based Learning (PBL) help students measure their conceptual understanding of the material being studied (Amalia et al., 2021). When compared to conventional learning models, PBL has advantages in improving students' mathematical understanding (Sari et al., 2021).

Meanwhile, the Project-Based Learning (PjBL) model emphasizes student involvement in a series of activities designed to discover and understand a concept through direct experience (Komarudin et al., 2020). Mathematics learning using the PjBL model is more effective than the conventional model (Pratama et al., 2020). Learning that applies the PjBL model has been proven to improve mathematical comprehension skills in both male and female students. The experiences and understanding built by students make PjBL significantly influential in the process of students' mathematical concept comprehension (Putri et al., 2023). In PjBL, teachers act as facilitators, mentors, and evaluators, while students work in groups to design solutions to real-world problems and produce final products in the form of reports, models, or presentations (Azizah, 2022). Both models are in line with the student-centered learning principle emphasized in the Merdeka Curriculum.

Based on these findings, both PBL and PjBL show potential in developing students' mathematical concept comprehension skills through investigative activities, problem solving, and meaningful learning experiences. However, the effectiveness of these two models can vary depending on the characteristics of the students, the type of learning tasks, and the learning context applied. Therefore, research is needed that directly compares the effectiveness of PBL and PjBL on mathematical concept understanding at the junior high school level. Thus, this study aims to analyze the effectiveness of Problem Based Learning and Project Based Learning on junior high school students' mathematical concept comprehension abilities and to provide an empirical description of the most optimal learning model to use to improve the quality of mathematics learning.

Method

This type of research is a quasi-experiment with a quantitative approach using a pretest-posttest control group design (Creswell, 2023). The population in this study was all seventh-grade students at a public junior high school in Yogyakarta. The research sample consisted of two classes, namely experimental class I, which was given the Problem-Based Learning (PBL) model treatment, and experimental class II, which was given the Project-Based Learning (PjBL) model treatment in mathematics learning of flat-sided shapes. Sampling was conducted using purposive sampling based on the researcher's considerations, based on the characteristics of the students' abilities that were considered to represent the research objectives.

Data collection was conducted using a test instrument designed to measure mathematical concept comprehension. Prior to testing, the instrument underwent content validity testing using Gregory's content validity technique, assisted by two experts (expert judgment). The purpose of content validity is to evaluate how well the items represent the domain of all possible items. The content validity results of the mathematical concept comprehension instrument obtained a score of 1.00 with a very high validity criterion.

In addition, the instrument's reliability was tested using Cronbach's Alpha. Reliability is needed to determine the extent to which the research instrument used consistently produces the same results when used in the same situation on repeated occasions. The reliability test results of the mathematical concept understanding instrument produced a reliability coefficient of 0.634 for multiple-choice questions and 0.722 for essay questions, both of which are in the high reliability category.

The pretest and posttest scores obtained from the students' mathematical concept understanding instrument were analyzed using a paired t-test to determine the increase in mathematical concept understanding after the learning model was applied. The learning model can be said to be effective if there is an increase in students' mathematical concept comprehension abilities with the application of the PBL and PjBL models. In addition, the post-test results were analyzed using an independent two-sample t-test to compare which learning model was more effective in terms of students' mathematical concept comprehension.

Result and Discussion

Result

1. Learning Implementation Outcomes

During the learning process, an observation sheet in the form of a checklist with “yes” or “no” options was used to monitor the implementation of learning activities. This was done as a sign that the implementation of learning activities was filled in by the mathematics teacher acting as an observer. Based on the observation results, the observation results of the learning implementation in the problem-based learning class and the project-based learning class were observed by the observer (class teacher) who observed the learning implementation process. The observation results of the learning implementation of the two experimental groups can be seen in Table 1.

Table 1. Percentage of Learning Implementation

Meeting	Activities			
	PBL Class		PjBL Class	
	Teacher	Student	Teacher	Student
1	92%	85%	93%	87%
2	92%	85%	87%	80%
3	92%	92%	87%	80%
4	92%	85%	93%	93%
5	92%	85%	87%	87%
Average	92%	86%	89%	85%

Based on Table 1, it can be seen that student and teacher activities in implementing PBL and PjBL classes met the implementation percentage of > 80%. Therefore, it can be concluded that learning was carried out well in accordance with the syntax of each learning model.

2. Data on Mathematical Concept Understanding

The learning process provided in experimental class I and experimental class II was conducted over 7 meetings. The first meeting was a pretest, the second to sixth meetings were learning activities, and the seventh meeting was a posttest. The learning activities in experimental class I used the problem-based learning (PBL) model, and experimental class II used the project-based learning (PjBL) model. Descriptive analysis aims to describe the data from the students' mathematical concept comprehension test results. The data described includes the mean score, ideal maximum score, ideal minimum score, maximum score, minimum score, standard deviation, and variance. The results of the mathematical concept comprehension test analysis are presented in Table 2.

Table 2. Descriptive Statistics of Mathematical Concept Understanding

Description	Experiment I (PBL)		Experiment II (PjBL)	
	pretest	*postest*	*pretest*	*postest*
Mean	59,69	79,38	56,41	77,66
Ideal Maximum Score	100	100	100	100
Ideal Minimum Score	0	0	0	0
Maximum Score	65	95	65	95
Minimum Score	40	70	30	45
Standard Deviation	6,83	6,69	9,09	8,71
Variance	46,67	44,76	82,64	75,78

Based on Table 2, before the PBL and PjBL models were implemented, the average scores of experiment class I and experiment class II did not reach 70. After receiving the PBL and PjBL models, the average scores of both classes exceeded 70. The frequency distribution (f) of mathematical concept understanding before and after the implementation of the learning models in both classes is presented in Table 3.

Table 3. Frequency Distribution of Mathematical Concept Understanding Ability

Score Interval	Criteria	Experiment I (PBL)				Experiment II (PjBL)			
		pretest		*Postest*		*pretest*		*postest*	
		f	%	*f*	%	*f*	%	*f*	%
$X > 70$	Complete	0	0	32	100	0	0	30	93,8
$X < 70$	Incomplete	32	100	0	0	32	100	2	6,2

Based on Table 3, it can be seen that before the PBL and PjBL learning models were implemented, no students had achieved mastery. However, after the treatment was given, the frequency of students achieving mastery increased significantly. This shows that the PBL and PjBL models can help improve students' mathematical concept comprehension skills.

3. Data Analysis

The test of the difference in means between pretest and posttest scores aims to determine whether the PBL and PjBL models can improve students' mathematical concept comprehension skills. A paired sample t-test was used to determine the effectiveness of the PBL and PjBL models. Previously, a univariate normality assumption test was conducted using the Kolmogorov-Smirnov test. The p-value of the normality test for the mathematical concept comprehension variable in experimental class I was 0.29 and in experimental class II was 0.2. Because the p-value > 0.05, the normality assumption in both classes was fulfilled. Thus, the paired sample t-test could be performed, and the results are presented in Table 4.

Table 4. Paired t-test result

Variable	Class	df	t_{count}	t_{table}	*p-value*
Mathematical Concept Understanding	Experiment I (PBL)	31	10,639	1,696	0,000
	Experiment II (PjBL)	31	11,155	1,696	0,000

Table 4 shows that for the variable of mathematical concept understanding in experimental class I and experimental class II, the p-value < 0.05 and $t_{count} > t_{table}$ were obtained. This can be stated that H_0 is rejected, so that the PBL and PjBL models are significantly effective in improving students' mathematical concept understanding abilities.

Next, to test the comparative effectiveness of the PBL and PjBL models on students' mathematical concept understanding abilities, an independent two-sample t-test was conducted. The aim was to determine which learning model was superior in terms of students' mathematical concept understanding abilities. Previously, univariate normality and variance homogeneity tests had been conducted. The results showed that for experimental class I, the p-value for the mathematical concept understanding variable was 0.21, and for experimental class II, the p-value was 0.08. The results of the homogeneity of variance test for both experimental classes for the mathematical concept understanding variable were 0.15. Thus, the assumptions of univariate normality and homogeneity of variance were met. Therefore, the independent two-sample t-test could be performed, and the results are presented in Table 5.

Table 5. Independent two sample t-test result

Variable	t	df	$t_{0,05(62)}$	*p-value*
Mathematical Concept Understanding	0,88	62	1,67	0,19

Based on Table 5, for the variable of mathematical concept understanding, $t_{0,05(62)} > t$ and p-value > 0.05, so at a significance level of 0.05, there is sufficient evidence to accept

H_0. Thus, the average score for mathematical concept understanding with the PBL model and the PjBL model is the same. Therefore, there is no difference in the effectiveness of the PBL model and the PjBL model in terms of mathematical concept understanding ability.

Discussion

The PBL model is implemented by presenting a problem to students to analyze and discuss in order to arrive at the best solution. Through PBL, students are actively involved in the learning process by exploring knowledge relevant to the problem given. In terms of conceptual understanding, the application of PBL learning has proven to be effective. This effectiveness can be seen from the pretest and posttest results, which show an improvement after the PBL model was implemented. These findings are consistent with research conducted by (Nurhidayah & Waskitoningtyas, 2023), which shows that the application of the PBL learning model can improve students' understanding of mathematical concepts. Relevant to the results of research by (Amalia et al., 2021), which shows that the use of the PBL model helps improve students' mathematical concept comprehension skills. Furthermore, research by (Indriani et al., 2023) shows that the PBL learning model is more effective than the direct instruction model in improving students' mathematical comprehension skills.

Based on the steps of the PBL model, there are stages that play a role in improving conceptual understanding, namely the first step of “orienting students to the problem” and the second step of “organizing students in learning activities.” In the first stage, teachers connect problems to real-life situations, making it easier for students to understand the context of problems related to mathematics learning. This activity helps students build prior knowledge and connect concepts they have learned to apply to new problems. Next, in the second stage, “facilitating independent and group investigation,” students begin to examine problems more systematically. Through group work and task sharing, students are encouraged to explore relevant concepts in finding solutions to the problems given.

Similarly, the PjBL model has been proven effective in terms of mathematical concept comprehension. Its effectiveness can be seen from the increase in mathematical concept comprehension scores after the PjBL model was implemented. This is in line with several previous studies. Students who learn with the PjBL model have a higher understanding of concepts than students who learn conventionally (Putri et al., 2023). In addition, the application of the PjBL model is effective in improving students' understanding of concepts, where their understanding of concepts after applying PjBL is higher than before it was applied (Yensy et al., 2022). The PjBL model allows for independent exploration and problem solving, making it effective in improving students' mathematical concept understanding (Ghaira & Vebrian, 2024).

Both the PBL and PjBL models are effective in terms of mathematical concept understanding. In general, the PBL and PjBL models have similar principles despite having different stages. In PBL, there is a step of “orienting to the problem” that focuses on the relevance to the problem, while in PjBL, there is a step of “designing project planning,” which is choosing a project topic. Both start from problems given by the teacher in class and require the active involvement of students in the learning process.

Conclusion

Based on the description of the results and discussion, it can be concluded that the PBL and PjBL models are effective in improving mathematical concept comprehension skills. PBL has been proven to be effective in improving concept comprehension through the active involvement of students in analyzing real problems and facilitating group discussions that encourage knowledge construction. Similarly, the

PjBL model is able to improve conceptual understanding through independent and collaborative project exploration processes so that students gain a more meaningful learning experience. There is no difference in the effectiveness of the PBL model and the PjBL model in terms of mathematical conceptual understanding. Both models make a positive contribution with learning mechanisms that are equally student-centered, emphasize knowledge construction, and provide ample opportunity for students to think critically, creatively, and solve problems. Overall, the results of this study confirm that PBL and PjBL are both suitable as alternative innovative learning models in an effort to improve junior high school students' understanding of mathematical concepts. Teachers can choose one of these two models by considering student characteristics, learning objectives, and the classroom context to achieve optimal learning outcomes.

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