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A Comparison of Problem-Based Learning and Reciprocal Teaching Model: Impacts on Math Understanding and Self-Concept

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Abstract

This study aims to describe: (1) the effectiveness of the Problem-Based Learning (PBL) model in terms of students' understanding of mathematical concepts and self-concept; (2) the effectiveness of the Reciprocal Teaching (RT) model in terms of students' understanding of mathematical concepts and self-concept; and (3) a comparison of the effectiveness of the Problem-Based Learning model with the Reciprocal Teaching model in terms of students' understanding of mathematical concepts and self-concept. The sample used in this study was classes VIII C and VIII D, each consisting of 32 students. Class VIII C was given the problem-based learning model treatment, while class VIII D was given the reciprocal teaching model treatment. Data analysis in this study used descriptive and inferential analysis. In inferential analysis, multivariate normality and covariance matrix homogeneity assumptions were tested. Since the assumptions were met, the analysis continued with a one-sample mean vector test and a one-sample t-test to assess the effectiveness of learning, followed by a comparative effectiveness test using T2 Hotelling's. The results of the study indicate that at a significance level of 5%, the following were obtained: (1) Problem-Based Learning (PBL) is effective in terms of students' understanding of mathematical concepts and self-concept abilities; (2) Reciprocal Teaching (RT) is effective in terms of students' understanding of mathematical concepts and self-concept abilities; (3) There is no difference in the effectiveness of the Problem-Based Learning (PBL) and Reciprocal Teaching (RT) models in terms of students' understanding of mathematical concepts and conceptual abilities. This means that both problem-based learning and reciprocal teaching are effective and can be used as alternative learning models implemented in schools to teach material on relationships and functions and to facilitate improvements in students' mathematical concept understanding and self-concept abilities.

Keywords: *Problem-Based Learning; Reciprocal Teaching; Mathematical Concept Understanding Ability; Self Concept*

Introduction

The objectives of mathematics learning are outlined in the graduate competency standards in the Regulation of the Minister of Education, Culture, Research, and Technology of the Republic of Indonesia Number 5 of 2022, which states that students should be able to demonstrate logical thinking skills using mathematical concepts, procedures, facts, and tools to solve problems related to themselves, their surroundings, and their community (Kemendikbudristek, 2022). Understanding concepts is one of the basic competencies in mathematics learning. It involves absorbing material, remembering formulas and concepts, applying them to simple cases, assessing the truth of a statement, and using formulas and theorems to solve problems (Isra & Mufit, 2023; Hendriana et al., 2017).

Several studies on the ability to understand mathematical concepts at the junior high school/Islamic junior high school level show that students' ability to understand mathematical concepts still needs to be improved (Klorina, 2023; Supriadi, Vitona, & Rinaldi, 2023). This happens because students have not met all the indicators of mathematical concept understanding ability (Utami & Kusumah, 2023). In addition, the results of a preliminary study conducted by Klorina at a junior high school in Bengkulu also showed this problem, namely based on the analysis of the results of students' test answers to questions containing indicators of conceptual understanding such as classifying objects based on whether or not the requirements for forming a concept are met, almost all students have not been able to meet these indicators because students still experience difficulties when solving questions (Klorina, 2023).

Internal factors that can influence students' conceptual understanding of the material are self-concept (Slameto, 2013). Mathematical self-concept as a perception or reference that a person has about himself includes a series of characteristics, attributes, qualities and shortcomings, abilities and limitations, values, and relationships that are known to the individual (Abakpa, Anyagh, & Tembe, 2020; Jhoselle Tus, 2020) Students who have a positive/high self-concept usually have an attitude that is always optimistic, dare to try new things, dare to fail, are self-confident, enthusiastic, feel valuable, behave and always think positively (Risnawati, 2013). In line with this opinion, students with high self-concept tend to answer mathematics problems better than students with medium and low self-concept (Supriadi et al., 2023).

The factors that can influence students' conceptual understanding ability are learning models (Slameto, 2013). Problem-based learning model is a learning model that begins the learning process by presenting problems in everyday life as a context for learning in the classroom (Haerullah & Hasan, 2017; Barret, 2017). Implementation of mathematics learning through the problem based learning model can improve students' conceptual understanding (Kamid et al., 2018; Amalia et al., 2021). The next learning model is reciprocal teaching which contains 4 strategies, namely question generating, clarifying, predicting, summarizing (Shoimin, 2014). Reciprocal teaching was developed to enhance students' understanding and develop meta-knowledge behavior, which is defined as thinking about and understanding what they know and do not know, including organizational procedures for managing the process (Mafarja et al., 2022; Mafarja et al., 2023). Reciprocal teaching model is effective in improving students' mathematical concept understanding abilities (Chotima et al., 2019; Amin & Sumendap, 2022; Ulpah & Zaenurrohman, 2020).

Based on the description above, there is no empirical evidence related to the results of research that examines and compares the effectiveness between the problem-based learning model and reciprocal teaching in terms of students' mathematical concept understanding and self-concept in relation and function materials. This has resulted in researchers being interested in researching this. With this research, it is hoped that it can help students be more interested and play an active role during the mathematics learning process at school, can explore their ideas and gain new knowledge on their own, and can add empirical evidence related to effective learning models to use when learning mathematics.

Method

The type of research used is quasi-experimental research with pretest-posttest nonequivalent group design using two experimental classes that will be given a pretest to determine the initial conditions of each class that is given treatment and posttest. The independent variables in this study are the Problem Based Learning (PBL) and Reciprocal Teaching (RT) models, the dependent variables are the ability to understand mathematical concepts and students' self-concept. The samples used in this study were classes VIII C and VIII D, each consisting of 32 students. Class VIII C was given the problem-based learning model treatment, while class VIII D was given the reciprocal teaching model treatment.

In this study, the instruments used were a mathematical concept understanding ability test, a non-test student self-concept questionnaire, and a teacher and student observation sheets during learning. The test instruments consisted of two parts: a pretest that assessed the mathematical concept understanding ability of the students before the treatment, and a posttest that assessed the mathematical concept understanding ability of the students after the treatment. The non-test instrument was a student self-concept questionnaire with 15 statements. Both test and non-test instruments were administered to students before and after treatment. Instruments were used for data collection in this study.

Analysis techniques used in this study is descriptive and inferential analysis. Descriptive analysis finds the average, standard deviation, minimum, and maximum scores for both before and after treatment data. The ability indicator data is analyzed with a minimum KKTP of 70 and a self-concept score in the high category (more than 50).The criteria for the results of the self-concept questionnaire measurement used are classification based on the ideal average $(\bar{x}_i)$ and the ideal standard deviation (sb_i) shown in Table 1.

Table 1. Categorization of student self concept (modified from Azwar, 2010)

Assessment Requirements	Score	Category
$\bar{x}_i + 1,5sb_i < x$	$60 < x$	Very high
$\bar{x}_i + 0,5sb_i < x \leq \bar{x}_i + 1,5sb_i$	$50 < x \leq 60$	High
$\bar{x}_i - 0,5sb_i < x \leq \bar{x}_i + 0,5sb_i$	$40 < x \leq 50$	Medium
$\bar{x}_i - 1,5sb_i < x \leq \bar{x}_i - 0,5sb_i$	$30 < x \leq 40$	Low
$x \leq \bar{x}_i - 1,5sb_i$	$x \leq 30$	Very low

Inferential analysis was conducted by analyzing the mathematical concept comprehension ability test scores and self-concept questionnaire scores. Before conducting the hypothesis test in the inferential analysis, the analysis assumption test was first conducted consisting of the multivariate normality test and the covariance matrix homogeneity test which showed that the data had met the requirements, namely valid and homogeneous. Furthermore, a hypothesis test was conducted, namely to test the effectiveness of learning using a one-sample average vector test to test the effectiveness before and after the application of the learning model and a one-sample t-test to determine which variables were significantly different, then continued with a comparative effectiveness test using the Hotelling's T^2 test.

Results and Discussion

Results

Descriptive Analysis

Table 2. Data on Students' Mathematical Concept Understanding Ability

Description	Descriptive Statistics of Data on Students' Mathematical Concept Understanding Ability			
	PBL Class		**RT Class**	
	Pretest	***Posttest***	***Pretest***	***Posttest***
Ideal Minimum Value	0	0	0	0
Minimum Value	10	50	10	40
Ideal Maximum Value	100	100	100	100
Maximum Value	55	100	55	100
Average	32,81	77,50	32,24	75,78
Standard Deviation	12,57	13,44	12,38	15,25
Variance	157,96	180,65	153,20	232,43

Table 3. Average and Percentage of Students' Mathematical Concept Understanding Ability

No	Indicator	PBL Class		RT Class	
		Pretest	***Postest***	***Pretest***	***Postest***
		Average (%)	**Average (%)**	**Average (%)**	**Average (%)**
1	Ability to restate a concept based on whether or not the requirements for stating the concept are met.	7,81 (39,06%)	17,34 (86,72%)	8,28 (41,41%)	18,13 (90,63%)
2	Ability to select examples and non-examples of concepts that have been studied.	7,34 (36,72%)	16,41 (82,03%)	7,50 (37,50%)	16,72 (83,59%)
3	Ability to relate various concepts	8,28 (41,41%)	16,09 (80,47%)	7,50 (37,50%)	15 (75%)
4	Ability to apply concepts in solving mathematical problems	5,16 (25,78%)	14,84 (74,22%)	5,00 (25%)	14,22 (71,09%)
5	Ability to use mathematical procedures in problem solving	4,22 (21,09%)	12,81 (64,06%)	4,06 (20,31%)	11,72 (58,59%)
Total Average (%)		6,56 (32,81%)	15,50 (77,50%)	6,47 (32,34%)	15,16 (75,78%)

Table 4. Student Self Concept Score Data

Description	Descriptive Statistics of Students' Self Concept Data			
	PBL Class		**RT Class**	
	Pretest	***Posttest***	***Pretest***	***Posttest***
Ideal Minimum Value	15	15	15	15
Minimum Value	33	48	33	48
Ideal Maximum Value	75	75	75	75
Maximum Value	58	71	58	73
Average	47,28	60,03	46,91	60,50
Standard Deviation	5,75	5,17	5,50	6,40
Variance	33,05	26,74	30,22	40,90

Table 5. Average and Percentage of Students' Self Concept Scores

No	Indicator	PBL Class		RT Class	
		Pretest	***Postest***	***Pretest***	***Postest***
		Average (%)	**Average (%)**	**Average (%)**	**Average (%)**
1	Perception of mathematical reasoning ability	3,11 (62,29%)	3,97 (79,38%)	3,09 (61,88%)	4,07 (81,46%)
2	Perception of mathematical skill ability	2,91 (58,13%)	3,94 (78,75%)	2,89 (57,71%)	3,89 (77,71%)
3	Self-evaluation of the learning process	3,25 (43,33%)	3,95 (52,71%)	3,20 (42,71%)	4,17 (55,63%)
4	Interest in learning mathematics	3,44 (45,83%)	4,11 (54,79%)	3,33 (44,38%)	4,01 (53,44%)
5	Response to difficulties in mathematics	2,99 (59,79%)	3,99 (79,79%)	3,08 (61,67%)	4,08 (81,67%)
Total Average (%)		3,14 (63,04%)	3,99 (80,04%)	3,12 (62,54%)	4,04 (80,67%)

Inferential Analysis

Table 6. Multivariate Normality Test Results

Kelas	Data	*p-value*
Experiment 1 (PBL)	*Pretest*	0.8378692
	Posttest	0.3840591
Experiment 2 (RT)	*Pretest*	0.365176
	Posttest	0.445212

Table 7. Homogeneity Covariance Matrix Test Results

	Pretest	*Posttest*
p-value	0.9158	0.569

Table 8. One Sample Mean Vector Test Results

Class	*T.2*	*P-value*
PBL	120.97	2.2e-16
RT	86.745	2.2e-16

Table 9. One Sample T-test Result

Variable	PBL		RT	
	T	*P-value*	*T*	*P-value*
KPKM	3.1566	0.003541	2.1451	0.03989
SC	10.973	3.331e-12	9.2872	1.818e-10

Comparative Test of Learning Effectiveness

Comparative test of learning effectiveness was conducted to determine the average of two independent samples. The data analyzed were data before and after treatment with the learning model. The hypothesis test used was T^2 Hotelling's. The decision criterion in this study was that H_0 was rejected if the p-value < 0.05, which was calculated using Rstudio software. The results of the comparative effectiveness test before treatment are presented in Table 10.

Table 10. Results of Comparison Test of Effectiveness Before Treatment

	T^2 Hotelling's
P-value	0.9592

Based on Table 10 above, it can be seen that in the test before being given treatment with a learning model or initial ability p-value > 0.05, so it can be concluded that there is no difference in initial ability between the two experimental classes. Furthermore, the results of the effectiveness comparison test after treatment are presented in the following table.

Table 11. Results of Comparison Test of Effectiveness After Treatment

	T^2 Hotelling's
P-value	0.8207

Based on Table 19 above, it can be seen that in the test after being given treatment with the learning model or final ability, the p-value > 0.05, so it can be concluded that there is no difference in effectiveness between the two experimental classes.

Discussion

The Effectiveness of the Problem-Based Learning Model in Terms of Students' Mathematical Concept Understanding and Self-Concept Ability

Implementation of learning with the PBL model in this study can be seen from the average percentage of teacher and student observations with the PBL model, which were 91.48% and 90.11% respectively. Both observation results are in the good category, because the implementation of learning is at a high percentage. The requirements for effectiveness in this study, the PBL model is said to be effective in improving the ability to understand mathematical concepts if the average final score meets the KKTP set by the school, which is 70. While for the aspect of student self-concept, the PBL model is said to be effective if the final score of the student is 50. The average ability to understand mathematical concepts of students after being given treatment has increased. The increase in the average ability to understand mathematical concepts of students is 44.69, where the average value before treatment is 32.81 and the average ability to understand mathematical concepts after treatment is 77.50.This is in line with the results Amalia, Puwaningsih, & Utami (2021) which shows that the average test score of students' mathematical concept understanding ability after being given PBL treatment experienced a quite significant increase.

Average increase in the indicator of the ability to restate concepts based on whether or not the requirements for stating the concept are met is 47.66%. Arends (2008) revealed that this ability is an important part of learning that involves conceptual understanding. Trianto (2007) states that in PBL learning, students are facilitated to understand and evaluate relevant concepts through given problems. The high increase in this indicator is due to PBL allowing students to clarify and evaluate their understanding intensively through group discussion and reflection. This is in line with research by Lestari

& Luritawaty (2021) the implementation of the PBL model can improve students' conceptual understanding through in-depth and collaborative problem-based learning. The next indicator is the ability to select examples and non-examples of learned concepts. In PBL classroom learning, the indicator for the ability to select examples and non-examples of learned concepts increased by 45.31. In the context of PBL, Rusman (2012) added that students are trained to select relevant information from complex problems to strengthen their understanding of the concepts being studied. The average increase in the indicator of the ability to select examples and non-examples of concepts that have been studied is lower than the indicator of the ability to restate concepts. This is in line with research by Lestari & Luritawaty (2021) supports that PBL can significantly improve students' ability to identify examples and non-examples, especially when accompanied by explicit guidance from educators. The increase in the indicator of the ability to link various concepts was 39,06. Arends (2008) explains that linking concepts is an integral part of mathematical understanding, because problems often involve more than one concept. In PBL, students learn to integrate the concepts they learn in solving complex problems (Lestari & Luritawaty, 2021). This is in line with research Marlina, Sunaryo, & Zamnah (2022) which found that students needed more time to build cross-concept understanding than to understand a single concept, but the benefits were significant for long-term learning.

Indicator of the ability to apply concepts in solving mathematical problems increased by 48.44. PBL can facilitate the development of this indicator because the main focus of PBL involves the application of concepts to authentic problems, making learning more relevant and meaningful for students, so that students are trained to understand how the concepts learned can be applied in various situations (Marlina et al., 2022). This is in line with research Riswari & Ermawati (2020) which concluded that learning with the PBL model significantly improved students' ability to apply mathematical concepts to contextual situations, thereby strengthening their understanding.

Indicator of the ability to use mathematical procedures in problem-solving. In the PBL class, this indicator increased by 42.97 points. This is because the ability to use mathematical procedures in problem-solving develops through students' direct experience in solving problems that require the logical application of procedures (Marlina et al., 2022). Although students can remember and apply mathematical procedures, they often have difficulty connecting them to more complex problem contexts without a strong conceptual understanding (Supriyadi, 2021). The application of procedures in problem solving requires time to practice and link the relationship between procedures and concepts, while the application of concepts can occur more quickly through a thorough understanding of the problem, although the two are related, the application of concepts is often easier to understand and apply first than the use of mathematical procedures which are more structured and require further practice (Lestari & Luritawaty, 2021).

Increase in the average student self-concept score was quite significant. The average increase was 12.75, with a mean score of 60.03. Students with positive/high self-concept are typically optimistic, willing to try new things, willing to fail, confident, enthusiastic, self-reliant, and have a positive attitude and mindset (Risnawati, 2013).

Based on the research results that have been described previously, it is known that the PBL model is effective in improving students' mathematical concept understanding and self-concept abilities. These results can be seen from the increase in the average ability to understand mathematical concepts and self-concept of students based on the one sample t-test obtained with a significance value of < 0.05, so it can be concluded that H_0 is rejected, which means that the average ability to understand mathematical concepts and self-concept of students in the PBL class is more than 70 and 50. This means that learning with the PBL model is effective in terms of students' mathematical concept understanding and self-concept abilities on the material of relations and functions. These results are in line with research by Kamid et al., (2018) which shows that learning by applying the PBL model helps students to construct existing knowledge with new knowledge that they learn independently, so that students will better understand the new concepts they get by discovering the concepts themselves.

The Effectiveness of the Reciprocal Teaching Model in Terms of Students' Mathematical Concept Understanding and Self-Concept Ability

Implementation of the RT model steps is observed in the observation of teacher and student activities which aims to determine the extent to which the model steps are implemented according to what has been prepared. Because learning is said to be effective if it meets the requirements, one of which is that learning is structured based on appropriate content, materials, methods and interaction patterns (Hamdayana, 2016). The implementation of learning with the RT model in this study can be seen from the average percentage of teacher and student observations with the RT model, which were 91.25% and 90.86% respectively.

Looking at the effectiveness requirements in this study, the RT model is said to be effective in improving the ability to understand mathematical concepts if the average final score meets the KKTP set by the school, which is 70. While for the aspect of student self-concept, the RT model is said to be effective if the final score of the student is 50. The average ability to understand mathematical concepts of students after being given treatment increased. The increase in the average ability to understand mathematical concepts of students was 43.54, where the average value before treatment was 32.24 and the average ability to understand mathematical concepts after treatment was 75.78. This is in line with the results of the study Ulpah & Zaenurrohman (2020) which shows that the average test score of students' mathematical concept understanding ability after being given RT treatment experienced a quite significant increase.

The average increase in the indicator of the ability to restate concepts based on whether or not the requirements for stating the concept in the RT class are met is 49.22%. The increase can occur because, in the RT model, students are required to actively summarize and re-explain the concepts that have been learned in their own language, which helps strengthen their understanding of the concept (Palinscar & Brown, 1984). The average increase in indicators of the ability to choose examples and non-examples of concepts that have been learned in the RT class is 46.09%. The increase can occur because discussions between students carried out in the RT model encourage them to identify examples and non-examples in a more in-depth way by exploring the concept in more detail and seeing its application in various situations (Tobias & Dweck, 2019).

The average increase in the indicator, namely the ability to link various concepts, was 37.05%. Ramlah & Osman (2020) found that the questioning and clarifying strategies in RT helped students link mathematical concepts more effectively, so that this process increased students' ability to see the relationships between concepts, which in turn increased their understanding of the material as a whole.

Indicators of the ability to apply concepts in solving mathematical problems. in the RT class increased by 46.09%. The increase can occur because active discussions in groups help students to be more confident in applying mathematical concepts in more complex contexts, so that the RT model is effective in improving students' ability to apply mathematical concepts in problem-solving situations (Koh, Lim, & Chia, 2021).

The last indicator is the ability to use mathematical procedures in solving problems increased by 38.28%. Zhang & Li (2019) found that although RT can help students remember procedural steps, this skill requires further practice to be fully mastered. In the study, despite improvements, the skill of following the correct procedure was still lower than the ability to apply the concept. The increase in the average score of students' self-concept was quite significant. The average increase was 13.59 with the average being 60.50. Reciprocal teaching according to Fadly (2022) presenting reciprocity between students both in pairs and in class by paying attention to three things, namely learning to remember, thinking and motivating oneself. Reciprocity between students in the reciprocal teaching model means the embodiment of dialogue between teachers and students, in this case students can act as if they were teachers (Leonard, Wibawa, & Suriani, 2019).

Based on the research results that have been described previously, it is known that the RT model is effective in improving students' mathematical concept understanding and self-concept abilities. These results can be seen from the increase in the average ability to understand mathematical concepts and self-concept of students based on the one sample t-test obtained with a significance value of < 0.05, so it can be concluded that H0 is rejected, which means that the average ability to understand mathematical concepts and self-concept of students in the RT class is more than 70 and 50. This means that learning with the RT model is effective in terms of students' mathematical concept understanding and self-concept abilities on the material of relations and functions. These results are in line with research Chotima et al., (2019) which shows that the reciprocal teaching model requires students to be more active and confident, because in this learning model students will learn the material given by the teacher themselves and students will convey the findings they have learned to their friends.

Comparison of the Effectiveness of Problem-based Learning Model with Reciprocal Teaching in Terms of Students' Mathematical Concept Understanding Ability and Self-Concept

The data analyzed were posttest data from students' mathematical concept understanding and self-concept abilities. Based on the results of previous tests, it was obtained that with a significance level of more than 0.05, which means that there is no difference in effectiveness between the Problem-Based Learning (PBL) and Reciprocal Teaching (RT) learning models in terms of students' mathematical concept understanding and self-concept abilities.

The absence of differences in effectiveness between the PBL and RT models does not mean that there are no differences in the results of the descriptive analysis. Based on the results of the descriptive analysis, there are differences in the average and percentage of improvement in the mathematical concept understanding ability test and the final score of students' self-concept. The average mathematical concept understanding ability in the PBL class is 77.50 with an average increase of 44.69. While in the RT class the average mathematical concept understanding ability is 75.78 with an average increase of 43.54. The figure has a difference that is not too far, namely 1.15. In addition, when viewed from the percentage of students who can meet the KKTP from the mathematical concept understanding ability test, the class with the PBL model is more than the RT class.

In the self-concept aspect, the average final score of the self-concept questionnaire of the PBL and RT classes was almost the same. The average final score of the self-concept questionnaire of the PBL and RT classes were 60.03 and 60.50, respectively. Meanwhile, the increase in the average self-concept score in the RT class was higher than in the PBL class. In the PBL class, the average increase in the self-concept score was 12.75, while the average increase in the self-concept score in the RT class was 13.59.

Conclusion

Conclusion of this study is: 1) Problem-based learning model (PBL) is effective in terms of the ability of grade VIII students in understanding mathematical concepts and self-concept on the material of Relationships and Functions; 2) Reciprocal Teaching (RT) learning model is effective in terms of the ability of grade VIII students in understanding mathematical concepts and self-concept on the material of Relationships and Functions. 3). There is no difference in the effectiveness of Problem-Based Learning (PBL) and Reciprocal Teaching (RT) learning models in terms of the ability to understand mathematical concepts and self-concept of VIII grade students on Relationship and Function material.

This study provides implications that the application of the reciprocal teaching model requires more precision and accuracy of teachers in understanding student abilities than the problem-based learning model. This is because, in the reciprocal teaching model, teachers must be able to choose the right students to act as "student teachers" who will then teach the material to their friends. In addition, students are not yet accustomed to the Reciprocal Teaching model so they still need to adapt to get maximum results. Teachers should form heterogeneous groups and ensure that each group member has a specific role during the discussion, such as discussion leader, presenter and recorder of discussion results to ensure that each student actively participates. Further research is needed on other variables, materials and subjects. This aims to obtain more diverse results in various aspects, so that it can improve the quality of mathematics learning in the future.

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