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ORIGINAL PAPER

The Effect of the Problem-Based Learning Model on the Mathematical Creative Thinking Ability of Seventh-Grade Students of Private Middle School Karya Pembangunan Deli Tua

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Abstract
This study aims to describe changes in the mathematical creative thinking abilities of students in the experimental and control classes and to analyze the differences in the increase in mathematical creative thinking abilities between students who received learning with the Problem-Based Learning (PBL) model and students who received conventional learning on the material of comparative value. This research was motivated by the low mathematical creative thinking ability of seventh-grade students of Karya Pembangunan Private Middle School, Deli Tua, especially in the aspect of flexibility and originality. The method used is quantitative with a quasi-experimental design, a nonequivalent control group design type. The study population was all 36 seventh-grade students, with the sample determined through a purposive sampling technique, namely class VII-A as the experimental class (n = 18) who received PBL learning and class VII-B as the control class (n = 18) who received conventional learning. The research instrument is in the form of a descriptive test consisting of 4 questions representing the indicators. Fluency, flexibility, originality, and elaboration were declared valid (0.702–0.721) and reliable (r_hitungCronbach's Alpha= 0.919). The results of the study showed that the average posttest score of the experimental class (12.8333) is higher than that of the control class (9.6667), with the N-Gain of the experimental class being 0.675. The control class was 0.352, both of which are in the medium category, but the magnitude of the increase in the experimental class is consistently higher than the control class. Because the data were not normally distributed (Shapiro-Wilk test, Sig. = 0.008), hypothesis testing used a nonparametric test. Mann-Whitney U test, and the value of Asymp. Sig. (2-tailed) = 0.000 < 0.05 is obtained, so H0 is rejected and Ha is accepted. It can be concluded that there is an influence of the model H_0 H_a Problem-Based Learning on the mathematical creative thinking abilities of class VII students of Karya Pembangunan Private Middle School, Deli Tua, on the material of comparative value.

Keywords:
Problem-Based Learning
Mathematical Creative Thinking Skills
Comparative Value

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INTRODUCTION

Education is an effort to realize the cultural inheritance from one generation to the next. Education makes this generation a role model for the teachings of previous generations.(Rahman, 2022)Education plays a very strategic and important role in improving the quality of human resources, realizing the nation's ideals, general welfare, and improving the nation's life. According to Law No. 20 of 2003, Article 12, paragraph 1, there are three pathways: informal, formal, and non-formal.(Fauzan, 2026).

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Mathematics is a subject that plays a crucial role in the development of science and technology. Strong mathematical skills are essential for facing the global challenges of the 21st century, including the ability to think creatively in mathematics.(Sari, 2025). Creative thinking skills are high-level thinking skills that are essential for students to solve various mathematical problems innovatively and flexibly (Andiyana et al., 2018). This skill is important to develop because students are not only required to obtain correct answers but also to be able to generate various problem-solving strategies, view problems from different perspectives, and explain ideas in detail. In junior high school mathematics, this skill is essential, especially in the material on comparative values, which is often related to everyday life situations.(Siregar et al., 2020). However, various research findings

However, various research findings indicate that students' mathematical creative thinking skills in Indonesia are still relatively low. A study of eighth-grade junior high school students on quadrilaterals and triangles showed that their creative thinking indicators were in the low category, with fluency of 94.75%, flexibility of 48.75%, originality of 21%, and elaboration of 18.5%.(Rapa, 2023)Similar findings were also found in seventh-grade junior high school students in the triangle material, with fluency achievements of 50.93%, flexibility of 46.14%, and originality of 33.33%.(Kadir, 2022). This indicates that the aspects of originality and elaboration are still weak points for students in general.

One of the reasons why students' creative thinking abilities at school are not yet optimal is that the learning process is still teacher-oriented and does not actively involve students. Hence, students are less directly involved in the learning process.(Julia, 2022)This is in line with research results which show that students generally have good fluency in solving routine problems.(Susilawati et al., 2025).

This situation was also found at Karya Pembangunan Private Junior High School in Deli Tua. Initial observations showed that the mathematics learning process was still dominated by lectures and routine practice exercises, resulting in students being less active in expressing ideas, rarely exploring different solutions, and tending to follow the procedures given by the teacher. The results of the initial test on the comparative material also supported this finding. Students were generally quite fluent in converting word problems into mathematical forms and demonstrated good elaboration in solving simple problems. However, they still had low levels of flexibility, tending to use only one solution method, and low levels of originality, as almost all students relied on textbook formulas for solving without developing alternative strategies. Errors in the final calculation stage were also still found due to students' lack of habit of re-checking their work, indicating weak elaboration on more complex problems.(Faturohman & Afriansyah, 2020).

If this condition is not addressed immediately, students are at risk of experiencing difficulties in dealing with non-routine and contextual questions that require reasoning and varied solution strategies, as required by 21st-century thinking competencies.(Arni, 2022)Therefore, a learning model is needed that is in-depth, not just imitating the procedures demonstrated by the teacher.

One learning model that is considered capable of addressing these issues is Problem-Based Learning (PBL). PBL is a learning model that uses real-world problems as the context for learning, thus training students to think creatively and develop problem-solving skills.(A. Sianturi, 2018)Through PBL, students are required to actively seek, analyze, and evaluate information to solve contextual problems, which ultimately helps improve students' mathematical creative thinking skills.(Selfiani, 2022). Comparative value material is considered suitable to be combined with PBL because this material is contextual and close to students' daily experiences, thus providing ample space for students to explore various problem-solving strategies.

Based on previous research, Problem-Based Learning has been widely used to improve creative thinking skills in mathematics across various mathematics learning topics. However, the Problem-Based Learning model has never been studied in the teaching of comparative value material in grade VII of SMP Swasta Karya Pembangunan Deli Tua. Therefore, this study is necessary to provide concrete evidence regarding the impact of the use of problem-based learning models on students' mathematical creative thinking skills in comparative value material.

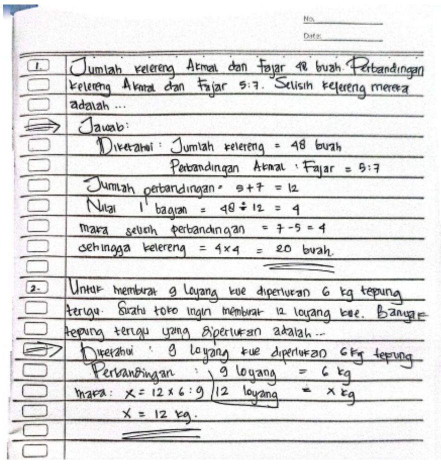

Figure 1 Student Work Results

Based on the results of the initial test conducted by seventh-grade students of Karya Pembangunan Private Middle School, Deli Tua, in solving comparative problems of equal value. In the first problem, the number of marbles Akmal and Fajar have is 48, and the ratio of Akmal to 7 is 5. What is the difference between their marbles?

In the first problem, the student fluently transformed the problem statement into mathematical data, immediately adding the comparative values, and then finding the value of one part without hesitation. This flow of work demonstrates fluency of thought because there are no interrupted steps.$(jumlah = 48, rasio = 5:7), (5 + 7 = 12)$

In the second question, the student also immediately recognized that the problem was a proportional ratio (as the pan increases, the flour also increases) and immediately constructed the ratio. This speed in recognizing this type of ratio is a form of fluency, even though the final calculation was incorrect.$8 : 6 = 12 : x$

In the first flexibility problem, it can be solved by finding the value of one part in another way, for example, by directly calculating the difference using the difference formula. Students who are able to show two different methods with the same result demonstrate the flexibility of creative thinking.$(selisih\ rasio \div jumlah\ rasio) \times total, (2 \div 12) \times 48 = 8$

The second question can also be solved in another way, for example, by first finding the flour requirement for 1 baking pan, then multiplying it by 12 baking pans. In the answer above, the student only used one method (cross multiplication), so the flexibility indicator is not fully visible.$(6 \div 8 = 0{,}75\ kg)(0{,}75 \times 12 = 9\ kg)$.

In terms of originality, these two questions are contextual (marbles and cake tins) so that they open up opportunities for students to produce original strategies, for example using comparison tables, section bar diagrams, or scale logic instead of textbook formulas.

In the answer above, the student is still using the standard solution pattern/book formula. There are no new strategies or different perspectives that reflect originality, so this aspect needs to be further developed.

In the elaboration of the first question, the student was quite elaborate, writing down each step in detail, finding the sum of the parts, the value of one part, the difference between the parts, and the final result. This detail makes it easier for readers to trace the student's thought process.

In the second question, the elaboration is not complete because the student did not recheck the results. Suppose the student elaborates the answer by rechecking. By comparing the results of the division, the calculation error in the final answer will be immediately detected.$x = 12\ kg.\ 6\ kg \div 8\ loyang = 0{,}75\ kg/loyang 0{,}75 \times 12 = 9\ kg$

Steps and final results for the first question

1. Value of 1 part= $48 \div 12 = 4$
2. Atma marbles= $5 \times 4 = 20\ buah$
3. Dawn marbles= $7 \times 4 = 28\ buah$
4. Difference= $28 - 20 = 8\ buah$

The answer to 8 in the first question is correct.

In the second question, the error occurred in the final division step. The student wrote down the correct result, but the answer sheet stated the final result, meaning the division of 72 was done with the number 6, not with the number 8. This indicates an error in determining the final division step.$x = (12 \times 6) \div 8{,}72 \div 8 = 9. x = 12\ kg$

Table 1. Student Answer Results

Stage	Student answer (wrong)	Correct answer
Comparison model	8 trays : 6kg = 12 trays : x kg	8 pans : 16 kg = 12 pans : x kg
Cross multiplication	$\times = (12 \times 6) \div 8$	$x = (12 \times 6) \div 8$
Product	$72 \div 8$	$72 \div 8$
Final distribution	$72 \div 6 = 12$	$72 \div 8 = 9$
The final result	$x = 12\ kg$	$x = 9\ kg$

Therefore, it is necessary to test empirically through experimental research regarding the effect of implementing the PBL model on students' mathematical creative thinking abilities.

Table 2 Initial Diagnosis Results

Indicator	Initial Percentage	Category
Fluency	33.25%	Not enough
Flexibility	32%	Not enough
Originality	32%	Not enough
Elaboration	33.25%	Not enough

Based on initial diagnostic results, students' mathematical creative thinking skills have not developed evenly. Students are relatively capable of identifying information and generating a single solution strategy, but still have difficulty generating more than one method, using a strategy different from the teacher's example, and explaining the solution in detail. This condition indicates that the aspects of flexibility, originality, and elaboration still need strengthening.

Learning is a process or effort undertaken by each person to achieve changes in behavior, which can be in the form of knowledge, skills, attitudes and positive values , as a result of experience from various materials that have been studied.(Lubis, 2024)The definition of learning can also be interpreted as all mental activities carried out by each group so that their behavior is different between before and after learning.(Siti Ma'rifah Setiawati & Guru, 2018). New experiences cause changes in behavior or reactions that occur, knowledge gained after learning, and practice activities.(Nasrianty et al., 2023).

In essence, it is a process, namely, regulating and organizing the environment around students so that it can foster and encourage students to carry out the learning process. In the educational process, students are both the subject and object of educational activities. Therefore, the meaning of the teaching process is student learning activities in achieving a teaching goal.(Cahyani, 2025)So, learning is an effort to organize the environment to create a learning environment. In learning, students learn to solve problems that must be solved actively.(Pane, 2017).

Mathematics education is a part of education that has a role in society because it is one of the factors that needs to be considered in the development of science and technology (Nurdalilah, 2018).

Mathematics itself is a very important subject to be taught at every level of education because it provides many benefits, such as helping in preparing for future careers, improving problem-solving skills, building character, helping to learn other knowledge, forming logical thought patterns, advancing thinking power and so on.(Gea, 2020).

The learning model is the highest level in the learning framework because it covers all levels within its scope.(Khayroiyah, 2018). Within a learning model, there are strategies that explain the operations, tools, or techniques students use in the process. Furthermore, within the learning strategy, there are many learning methods that explain the steps to achieve learning objectives. This level serves to explain the relationships within the learning framework. The term learning model is often interpreted as a learning approach in the classroom.(Wahyuni, 2024).

According to(Rahmadani, 2024)Problem-based learning is a learning model approach that challenges students to "learn how to learn," working in groups to find solutions to real-world problems. Problems are used to pique students' curiosity about the intended learning. Problems are presented to students before they learn the concepts or material related to the problem to be solved.

Problem-Based Learning (PBL) is a learning model that focuses on presenting authentic and meaningful problems as a means of investigation and inquiry. This model positions students as active problem solvers from the beginning of the learning process, with the teacher acting as a facilitator.(Selfiani, 2022)

Creative thinking is an organized thought process that pays attention to intuition, triggers imagination, reveals new possibilities, opens up amazing perspectives, and generates unexpected ideas by combining logical thinking. It helps turn these ideas into creative solutions and uses divergent thinking to find ideas to solve problems.(Astuti, 2022). According to(Wulandari, 2022)is an individual's ability to solve problems unusually and differently from other people.

Mathematical creative thinking is the ability to solve problems and strengthen logical and deductive thinking by combining various ideas, methods, or approaches innovatively, so as to be able to make arguments and improve the abilities needed by students.(Ndiung, 2019)The importance of creative mathematical thinking is also stated by Kiesswetter, who states that flexible thinking skills, which are one aspect of creative thinking skills, are important skills that students must have in solving mathematical problems.(Dwidayati, 2017).

Creative thinking is a skill that students must possess. Mathematical creative thinking refers to an individual's ability to think with the aim of identifying new, differentiated ideas and creating new, unusual, and original ideas that yield definite and precise results. High-Order Thinking (HOT) categorizes mathematical creative thinking as a key component. Mathematical creative thinking is considered essential in the educational process.(Astria, 2023).

The importance of mathematical creative thinking skills is to teach students more complex thinking processes in solving mathematical problems. Students learn to connect their existing knowledge by viewing problems from broader or different perspectives. To determine the level of mathematical creative thinking skills, we can observe aspects of fluency, flexibility, originality, and elaboration.(Ramadhani, 2022).

Creative thinking is an important competency that students must possess. It not only generates new ideas but also allows them to solve problems innovatively.(Saputra, 2025). According to(Husamah, 2018)Creative thinking skills are an important aspect in creating innovation and finding ideas to solve problems. Creative thinking can train students to develop many ideas and arguments, and ask several questions.

METHODOLOGY

This study used a quantitative approach with a quasi-experimental design. The design used was a nonequivalent control group design because this study involved two classes that were not selected randomly: the experimental class and the control class. The experimental class was given treatment in the form of learning with the Problem-Based Learning (PBL) model, while the control class was given conventional learning. Both classes were given a pre-test before the treatment and a post-test after the treatment to determine differences in students' mathematical creative thinking abilities (Sugiyono, 2020). Population is a general area consisting of objects/subjects that have special properties and characteristics determined by research to be studied, and then conclusions are drawn (Sugiyono, 2020). The population in this study was all seventh-grade students of Karya Pembangunan Private Middle School, Deli Tua, consisting of 2 classes and a total of 36 students in the even semester of the 2025/2026 academic year. Population data can be seen in the table below:

In this study, the researcher used a purposive sampling technique, a sampling technique based on previously known population characteristics. Based on the results obtained, class VII-A, which uses the Problem-Based Learning model, was chosen as the experimental class because the study used a class that had been administratively formed, and group selection was not carried out randomly among students. The experimental and control classes were determined based on considerations of school availability and schedule suitability. Initial ability equivalence was then checked based on pretest data.

A research instrument is a tool used by researchers to collect information about research data to answer the problems in the research. The instrument used is a mathematical creative thinking ability test in the form of descriptive questions (*essay*) on the comparative material of value. This instrument is used in two stages of measurement, namely pre-test measurement to measure students' initial abilities before treatment, and post-test measurement to measure students' final abilities after treatment, both in the experimental class and the control class. The instrument grid is arranged based on four indicators of mathematical creative thinking ability, as follows. Validity Test, Reliability Test, Difficulty Level Test, Discriminatory Power Test

The data collection techniques used to collect the information needed in this research are: Observation, Test, and documentation. Quantitative data analysis and processing were conducted by conducting statistical tests on the post-test results from the experimental class. However, before conducting statistical analysis on the data, normality and homogeneity of variance tests and a t-test were first performed. After these three tests were conducted, a test for equality of the two means was then conducted. The steps in data processing are as follows: Normality Test, Homogeneity Test, t-test

RESULTS & DISCUSSION

Instrument Test Results

1 Validity Test Results

Validity testing was conducted to determine whether each question in the research instrument was able to measure mathematical creative thinking skills according to the predetermined indicators. This study used a measuring instrument consisting of four questions, each representing one indicator of mathematical creative thinking skills. Validity testing was conducted using the Pearson product-moment correlation method, calculated using SPSS. The instrument was pilot-tested on 18 respondents.

Table 3 Validity Test Results

Soal	**Indicator**	**r count**	**Sig**	**r.table**	**Information**
1	Smoothness	0.874	0,000	0.468	Valid
2	Flexibility	0.940	0,000	0.468	Valid
3	Original	0.953	0,000	0.468	Valid
4	Elaboration	0.841	0,000	0.468	Valid

Based on Table 3, the results of the validity test using the Product Moment correlation show that the significance value of the four questions is below the 5% significance level (sig = 0.000), so that all questions on the mathematical creative thinking ability test instrument are declared valid and suitable for use in collecting research data.

2 Reliability Test

Reliability testing is conducted to determine how consistent or stable the research instrument is. A reliable measuring instrument indicates that the questions in the instrument consistently measure the abilities being studied.

Table 4 Reliability Test

Cronbach's Alpha	Number of Questions	Information
0.919	>0.6	Reliability

Based on Table 4, the reliability test results using the Cronbach's Alpha formula obtained a value of 0.919. This value is greater than the minimum criterion of 0.6, so the mathematical creative thinking ability test instrument is declared reliable and consistent when used repeatedly to measure the same object.

3 Levels of Difficulty

The difficulty level test was conducted to determine the difficulty of each question used in the mathematical creative thinking ability test instrument. The difficulty level indicates how many students answered each question correctly. Difficulty level analysis was performed by calculating the difficulty index (P) for each question individually. The criteria for interpreting the difficulty index used in this study are as follows.

Table 5. Level of Difficulty

Indicator	P Index	Interpretation
Smoothness	0.625	Currently
Flexibility	0.667	Currently
Authenticity	0.694	Currently
Elaboration	0.667	Currently

Based on the results of the difficulty level analysis in Table 5, it can be seen that all test items have a difficulty index (P) in the range of 0.30–0.70. The difficulty index value for the fluency indicator is 0.625, flexibility 0.667, originality 0.694, and elaboration 0.667. Based on the difficulty index classification criteria, the four test items are included in the moderate category. This indicates that the instrument has a fairly proportional level of difficulty, neither too easy nor too difficult, so that it can differentiate students' mathematical creative thinking abilities.

4. Distinguishing Power Test

A discriminatory power test was conducted to determine how well each question differentiated high-achieving students from low-achieving students. The discriminatory power test in this study was conducted on a mathematical creative thinking ability test instrument consisting of four questions: fluency, flexibility, originality, and elaboration. The results of the discriminatory power test for each question are presented in the following table.

Table 6 Distinguishing Power Test

Indicator	Grade D	Classification
Smoothness	0.773	Good
Flexibility	0.891	Very well
Authenticity	0.917	Very well
Elaboration	0.704	Good

Based on Table 6, the results of the discriminatory power test using the corrected item-total correlation value show that all four test items have r values above 0.70, ranging from 0.704 to 0.917. The highest value was obtained for the originality indicator (0.917) and the lowest value for the elaboration indicator (0.704). Based on the classification criteria used, the three test items (flexibility, originality) are included in the very good category, while the other two items (fluency, elaboration) are included in the good category. Thus, all test items have sufficient discriminatory power to distinguish between high-ability students and low-ability students.

Description of Research Results

1 Pretest

BeforeAfter administering the treatment, the researcher administered a pretest to students in the experimental and control classes to determine their prior abilities. The pretest results were then analyzed descriptively to determine the lowest, highest, average, and level of variation in the data for each class. The results of the descriptive statistical analysis of the pretest in the experimental and control classes are shown in the following table.

Table 7 Pretest Descriptive Statistics

Statistics	Experimental Class	Control Class
Minimum Value	3.00	2.00
Maximum Value	8.00	11.00
Average (Mean)	6,0556	5,8333
Standard Deviation	1.39209	2,14887

Based on Table 7, it can be seen that the pretest results in the experimental class have the lowest value of 3.00 and the highest value of 8.00. The average (mean) value is 6.0556, while the standard deviation is 1.39209. Meanwhile, the control class gets the lowest value of 2.00 and the highest value of 11.00, with an average (mean) of 5.8333 and a standard deviation of 2.14887.

Based on the average scores, it can be seen that the initial abilities of students in the experimental and control classes were almost the same, with an average score of 6.0556 for the experimental class and 5.8333 for the control class. This indicates that the initial abilities of both classes before being given the treatment were almost the same. The pretest data was then used as a reference in evaluating changes in student abilities after they received certain treatments.

2 Posttest

After being given treatment in the experimental and control classes, both classes were given a posttest to analyze students' creative mathematical thinking skills after the learning process was completed. The posttest results were then analyzed descriptively to determine the lowest, highest, average, and variation scores in each class. The results of the descriptive statistical analysis of the posttests for the experimental and control classes are shown in the following table.

Table 8 Posttest Descriptive Statistics

Statistics	Experimental Class	Control Class
Minimum Value	11.00	6.00
Maximum Value	14.00	13.00
Average (Mean)	12,8333	9,6667
Standard Deviation	0.78591	1.84710

Based on Table 8, it can be seen that the posttest results of the experimental class obtained a minimum score of 11.00 and a maximum score of 14.00, with an average score (mean) of 12.8333 and a standard deviation of 0.78591. Meanwhile, the control class obtained a minimum score of 6.00 and a maximum score of 13.00, with an average score (mean) of 9.6667 and a standard deviation of 1.84710.

Based on the average posttest score, it can be seen that the average mathematical creative thinking ability of students in the experimental class is higher than that of the control class. The experimental class obtained an average of 12.8333, while the control class was 9.6667. This indicates a difference in students' mathematical creative thinking abilities after learning, where the experimental class that received the Problem-Based Learning (PBL) model treatment had a higher average posttest result than the control class.

3 Gain

To determine the improvement in students' mathematical creative thinking skills before and after the learning process, an N-Gain analysis was conducted on the pre- and post-test results in the experimental and control classes. The N-Gain calculation was performed by comparing the difference in the average score between the posttest and pretest with the difference between the highest score and the average pretest score. The results of the N-Gain calculations for both classes can be seen in the table below.

Table 9 N-Gain Results of Experimental and Control Classes

Class	Pretest Average	Posttest Average	N-Gain	Category
Experiment	6,0556	12,8333	0.675	Tall
Control	5,8333	9,6667	0.352	Currently

Based on Table 9, it was found that the N-Gain value of the experimental class was 0.675, which is included in the moderate category, while the N-Gain value of the control class was 0.352, which is also included in the moderate category. Although both classes are in the same improvement category, the N-Gain value of the experimental class is higher than that of the control class, which indicates that the improvement in students' mathematical creative thinking abilities in the experimental class is better than in the control class.

In the experimental class, the average students' mathematical creative thinking ability increased from 6.0556 in the pretest to 12.8333 in the posttest. Meanwhile, in the control class, the average students' mathematical creative thinking ability increased from 5.8333 in the pretest to 9.6667 in the posttest. This difference in the magnitude of the increase strengthens the indication that the application of the learning model in the experimental class has a better influence on improving students' mathematical creative thinking ability compared to the control class.

Thus, the N-Gain calculation results show that students' mathematical creative thinking skills using the Problem-Based Learning (PBL) model improved significantly compared to those in the control class. These results indicate that implementing the Problem-Based Learning model can help improve students' mathematical creative thinking skills.

4 Results Per Indicator

To find out the increase in students' mathematical creative thinking abilities in more detail, an analysis was conducted on each indicator of mathematical creative thinking ability. The indicators analyzed included fluency in speaking, adaptability, creativity in generating new ideas, and the ability to develop ideas further. This analysis was conducted by comparing the results of the initial and final trials in the experimental and control classes. The scores obtained for each indicator are as follows.

Table 10 Results Per Indicator

Indicator	Mean pretest	Mean posttest	Δ experiment	Mean pretest	Mean posttest	Δ Control
Fluency	1.39	3.28	1.89	1.72	2.44	0.72
Flexibility	1.83	3.39	1.56	1.39	2.56	1.17
Originality	1.33	3.39	2.06	1.44	2.28	0.84
Elaboration	1.67	3.17	1.50	1.61	2.06	0.45

In terms of fluency, the experimental class's average score increased from 1.39 in the pretest to 3.28 in the posttest, representing a 1.89-point increase. Meanwhile, the control class's average score increased from 1.72 to 2.44, representing a 0.72-point increase. This indicates that students' fluency in the experimental class improved significantly compared to the control class.

On the flexibility indicator, the experimental class's average increased from 1.83 to 3.39, representing a 1.56-point increase. In the control class, the average increased from 1.39 to 2.56, representing a 1.17% increase. Thus, the experimental class also demonstrated greater improvement.

In terms of originality, the experimental class's average score increased from 1.33 in the pretest to 3.39 in the posttest, representing a 2.06 percent increase. Meanwhile, in the control class, it increased from 1.44 to 2.28, representing a 0.84 percent increase. The experimental class experienced the largest increase in originality, at 2.06 percent.

On the elaboration indicator, the average for the experimental class increased from 1.67 to 3.17, representing an increase of 1.50. In the control class, it increased from 1.61 to 2.06, representing an increase of 0.45.

Overall, the four indicators of mathematical creative thinking ability showed a greater increase in the experimental class compared to the control class. The increases in the experimental class were fluency of 1.89, flexibility of 1.56, originality of 2.06, and elaboration of 1.50, respectively. Meanwhile, in the control class, the increases were 0.72, 1.17, 0.84, and 0.45, respectively. These results indicate that the class that received learning with the Problem-Based Learning (PBL) model experienced a higher increase in mathematical creative thinking ability than the control class. The indicator with the highest increase in the experimental class was originality of 2.06, while the lowest increase was in the elaboration indicator of 1.50.

4 Prerequisite and Hypothesis Tests

Prerequisite tests were conducted before hypothesis testing to determine the appropriate type of statistical analysis based on the characteristics of the research data. The prerequisite tests in this study included a normality test for the data on students' mathematical creative thinking skills in the experimental and control classes. The normality test was carried out using the Shapiro-Wilk method, and the significance level used was 5% ($\alpha = 0.05$).

After the requirement test is completed, a hypothesis test is then conducted to determine whether the Problem-Based Learning model has an influence on students' mathematical creative thinking abilities. The selection of the hypothesis test method is adjusted to the results of the requirement test. If the data meets the normality requirements, then a parametric test can be used, whereas if the data does not follow a normal distribution, then a nonparametric test is used. Thus, the results of the normality test show that the data do not follow a normal distribution; therefore, the hypothesis test is carried out using the Mann-Whitney U test. The test is used to determine whether there are differences in mathematical creative thinking abilities between students in the experimental class who received learning with the Problem-Based Learning model and students in the control class.

A Normality

The normality test was used to determine whether the data on students' mathematical creative thinking abilities in the experimental and control classes were normally distributed. Since each group consisted of 18 students, the normality test was conducted using the Shapiro-Wilk method with a significance level of 5% ($\alpha = 0.05$). Data are considered normally distributed if the significance value is greater than 0.05, while if the significance value is less than 0.05, the data are not normally distributed. The results of the normality test are presented in the following table.

Table 11 Normality Test

Data	Shapiro-Wilk Statistics	df	Sig	Information
*Pretest*Experiment	0,937	18	0.257	Normal
*Posttest*Experiment	0.850	18	0.008	Abnormal
*Pretest*Control	0.965	18	0.702	Normal
*Posttest*Control	0.957	18	0.541	Normal

Based on the results of the Shapiro-Wilk normality test in Table 11, the significance value for the experimental pretest was 0.257, the experimental posttest was 0.008, the control pretest was 0.702, and the control posttest was 0.541. With a significance level of 0.05, the results of the experimental pretest, control pretest, and control posttest all had significance values greater than 0.05, so the three datasets can be said to be normally distributed. The experimental posttest had a significance level of 0.008, which is smaller than 0.05, so it can be concluded that the data do not follow a normal distribution.

Thus, because the data do not meet the normality assumption, the hypothesis testing does not use the parametric independent-samples t-test, but uses the nonparametric Mann-Whitney U test. The Mann-Whitney U test is used to determine whether there is a difference in mathematical creative thinking ability between students in the experimental class and the control class. If the significance value is greater than 0.05, then the null hypothesis (H_0) is accepted, and the alternative hypothesis (H_a) is rejected, meaning that there is no significant difference between students' mathematical creative thinking ability in the experimental class and the control class.

2 Mann-Whitney U Test

The Mann–Whitney U test was used to examine whether there were differences in mathematical creative thinking abilities between students in the experimental class and the control class based on post-learning test scores. The test was conducted with a significance level of 0.05. The criteria for making decisions were based on the significance value (Asymp.). If the significance value (Sig.2-tailed) is less than 0.05, then the null hypothesis () is rejected, and the alternative hypothesis () is accepted, meaning there is a significant difference between the experimental class and the control class. If the significance value is greater than 0.05, then the null hypothesis is accepted, and the alternative hypothesis is rejected, meaning there is no significant difference between the two groups.$H_0 H_2$

Table 12 Mann-Whitney U Test

Group	N	Mean Rank	Mann-Whitney University	Z	Asymp.sig.(2-tailed)	Information
Experimental Class	18	26.44	15,500	-4,725	0,000	Significant
Control Class	18	10.56				
Total	36					

Based on the results of the hypothesis test using the Mann–Whitney U test, a value of 15.500 was obtained, a Z value of -4.725, and an Asymp. Sig. (2-tailed) value of 0.000. Because the significance value of 0.000 < 0.05, the null hypothesis () was rejected and the alternative hypothesis () was accepted. Thus, there was a clear difference between the mathematical creative thinking abilities of students in the experimental class and the control class based on the results of the post-test. The experimental class got a Mean Rank of 26.44, while the control class got a Mean Rank of 10.56 based on the Mean Rank value. There was a difference in the distribution of post-test scores for mathematical creative thinking abilities between the experimental class and the control class.$H_0 H_a$

2 Improvement Analysis

To determine the increase in students' mathematical creative thinking abilities before and after being given treatment, a comparison was made between the average pretest and posttest scores in the experimental class and the control class. The comparison was presented in the form of a graph so that changes in both classes could be seen clearly.

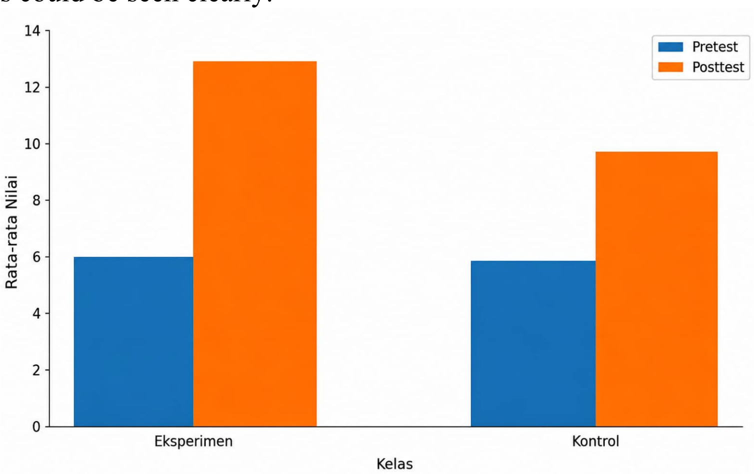

Figure 1 Graph of Average Increase in Pretest and Posttest

Based on the graph above, the average mathematical creative thinking ability in both classes increased. The experimental class increased from6.0556 to 12.8333, while the control class rose from 5.8333 to 9.6667.

Thus, descriptively, it can be concluded that the students' mathematical creative thinking skills in the experimental class were better than those in the control class. These results indicate that students in the experimental class experienced greater improvement in their abilities compared to before.

3 Hypotheses

Comparisons between groups were conducted to determine differences in the increase in the mathematical creative thinking abilities of students in the experimental class using the Problem-Based Learning model, with a control class implementing conventional learning. Based on the results of the N-Gain analysis, there was an average increase in mathematical creative thinking skills in both classes.

Based on Table 4.8, it can be seen that the average N-Gain in the experimental class was 0.675, which falls into the moderate category. In contrast, the control class had an average N-Gain of 0.352, which falls into the moderate category. This indicates that, descriptively, the increase in mathematical creative thinking ability and self-efficacy in the experimental class was better than that of students in the control class.

Based on the Mann–Whitney U test, the Asymp. Sig. (2-tailed) value is 0.000 < 0.05, so the null hypothesis () is rejected, and the alternative hypothesis () is accepted. This means that there is a difference in mathematical creative thinking ability between the experimental class and the control class. The average rating value of the experimental class (26.44) is greater than that of the control class (10.56), so the problem-based learning model has a better impact on students' mathematical creative thinking ability.H_0H_a

4 Implementation of PBL

During the implementation of the Problem-Based Learning (PBL) model in the learning process, observations were conducted to determine the extent to which the stages or syntax of the PBL model could be implemented during the learning activities. The results of the observation of the implementation of the PBL model from the first meeting to the end are presented.

Table 13 Results of Observations on PBL Implementation

No	PBL steps/syntax	Meeting 1	Meeting 2	Meeting 3	Meeting 4
1	Student orientation to problems	3	3	4	4
2	Organizing students for learning	2	3	3	4
3	Guiding individual/group investigations	3	3	4	4
4	Develop and present work results	3	3	3	4
5	Analyze and evaluate the problem-solving process	3	3	4	4
	Total Score	14	15	18	20
	Maximum Score	20	20	20	20
	Percentage of implementation	65%	75%	90%	100%
	Category	Good	Good	Very good	Very good

Based on Table 13, the observation results show that each PBL phase implemented in the learning series fell into the good to excellent category. This observation can support the fidelity of implementation, but cannot guarantee that differences in results are truly due to PBL and not other factors.

DISCUSSION

This study aims to describe the mathematical creative thinking abilities of students in classes that receive Problem-Based Learning (PBL) and classes that receive conventional learning, and to analyze whether the improvements in the two classes are significantly different.

Before the learning outcome data were analyzed, the mathematical creative thinking ability test instrument was first tested for its feasibility. The validity test results showed that all test items were valid (r count 0.841–0.953; Sig. = 0.000), the reliability test showed that the instrument was very reliable (Cronbach's Alpha = 0.919), and the discrimination test showed that all test items were classified as good to very good (D = 0.704–0.917). This indicates that the instrument used is feasible and reliable for measuring students' mathematical creative thinking abilities.

The descriptive results show that the initial (pretest) abilities of both classes were relatively equal, with an average of 6.0556 for the experimental class and 5.8333 for the control class. After being given treatment, the posttest average of the experimental class increased to 12.8333, significantly higher than the control class, which only achieved 9.6667. This increase was also confirmed through the N-Gain, where the experimental class obtained an N-Gain of 0.675, while the control class only obtained 0.352; both were in the medium category, but the magnitude of the increase in the experimental class was much higher. This finding is consistent with the results of the analysis per indicator, where all indicators of mathematical creative thinking ability, fluency, flexibility, originality, and elaboration in the experimental class increased more sharply than in the control class. The most prominent increase occurred in the originality aspect, in line with the findings of the preliminary study in the research background, which showed that the flexibility and originality aspects were students' weak points before the treatment was given. This indicates that the PBL syntax, especially at the investigation and solution presentation stages, is quite effective in encouraging students to produce more diverse solution strategies and not just imitate the procedures exemplified by the teacher.

The prerequisite test showed that the posttest data of the experimental class was not normally distributed (Sig. = 0.008), so the hypothesis testing was carried out using the nonparametric Mann-Whitney U test. The test results showed Asymp. Sig. (2-tailed) = 0.000 <0.05, so H0 was rejected, and Ha was accepted, which means there was a significant difference in mathematical creative thinking ability between the experimental class and the control class, with the Mean Rank of the experimental class (26.44) much higher than the control class (10.56). This finding answers the problem formulation and research objectives, while strengthening the results of previous studies which show that PBL is effective in improving students' mathematical creative thinking abilities (Selfiani, 2022; Sefrinal, 2019). Theoretically, this is in line with the characteristics of PBL, which places contextual problems as the starting point of learning, so that students actively seek, analyze, and evaluate information to solve problems, a process that helps train students' divergent and convergent thinking abilities.

The success of PBL implementation in the experimental class was also supported by the results of observations of learning implementation, which showed a consistent upward trend from the first meeting (65%, good category) to the fourth meeting (100%, very good category). This consistency indicates that teachers are increasingly accustomed to implementing the complete PBL steps, thus supporting the belief that the difference in learning outcomes between the two classes is indeed related to the learning model used.

Research Limitations

1. No formal statistical tests were conducted to test for equivalence of initial abilities (pretest) between the experimental and control classes; equivalence was only examined descriptively based on the mean scores (6.0556 versus 5.8333), so the possibility of undetected differences in initial abilities cannot be completely ruled out.

2. The research sample was limited to 36 students (18 students per class) from one school using a purposive sampling technique, not random assignment, so the research results cannot necessarily be generalized to the wider population of junior high school students.
3. The research was only conducted on one material, namely comparison of values, over a period of 4 meetings, so it is not yet known whether the effect of the PBL model on mathematical creative thinking skills will be consistent on other mathematical materials or in a longer intervention duration.
4. The posttest data of the experimental class were not normally distributed, so the analysis was limited to nonparametric tests (Mann-Whitney U), which provide information on differences in ranks, not direct differences in means as in parametric tests.
5. The mathematical creative thinking ability instrument consists of only four questions, with one item for each indicator. This condition causes the score for each indicator to be highly dependent on the student's response to a single problem context and can limit the breadth of representation of the mathematical creative thinking ability construct.
6. One assessor carries out scoring of descriptive answers, so the potential for subjectivity in scoring cannot be eliminated.
7. The difficulty level analysis results indicate that all items are in the easy category (index 0.895–0.986), with no items of medium or high difficulty. This condition results in the instrument being less than optimal in measuring students' mathematical creative thinking abilities at more challenging levels, so the variation in abilities of high-achieving students may not be fully revealed.

CONCLUSION

The mathematical creative thinking ability of experimental class students using the Problem Based Learning (PBL) learning model increased, from a pretest average of 6.0556 to a posttest average of 12.8333, with an N-Gain value of 0.675, which is included in the moderate category. The mathematical creative thinking ability of control class students who followed conventional learning also increased, from a pretest average of 5.8333 to a posttest average of 9.6667, with an N-Gain value of 0.352, which is in the medium category, much lower than the experimental class. There is a significant difference in mathematical creative thinking ability between the experimental class and the control class after being given treatment, as shown by the results of the Mann-Whitney U test with a value of U = 15.500, Z = -4.725, and Asymp. Sig. (2-tailed) = 0.000 (<0.05), so the null hypothesis is rejected.$H_0 H_a$. The results of observations of the implementation of learning showed that the implementation of the PBL model syntax in the experimental class went from good to very good, with the percentage of implementation increasing from 65% at the first meeting to 100% at the fourth meeting. It can be concluded that the Problem-Based Learning (PBL) learning model has an effect on improving the mathematical creative thinking skills of grade VII students on the comparative value material at Karya Pembangunan Deli Tua Private Middle School.

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