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The Effectiveness of Problem-Based Learning Model on Students' Learning Independence and Mathematical Creative Thinking Abilities

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Abstract

This study investigates the effectiveness of the Problem-Based Learning (PBL) model in fostering students' learning independence and mathematical creative thinking skills. The research was conducted with seventh-grade students at SMP Negeri 2 Mesuji, Lampung, during the odd semester of the 2024/2025 academic year. The population comprised 216 students across seven classes, from which two classes were selected using cluster random sampling. A pretest–posttest control group design was employed. Data were collected through essay tests on the topic of social arithmetic and questionnaires assessing students' learning independence. The data were analyzed using t-tests, N-Gain analysis, and one-proportion z-tests. The results indicate that the PBL model was more effective than conventional learning in enhancing both mathematical creative thinking and learning independence. The experimental group achieved a significantly higher average N-Gain score than the control group. Furthermore, over 60% of students in the experimental class attained a "good" category in learning independence after the intervention. Improvements in creative thinking indicators fluency, flexibility, originality, and elaboration were also more pronounced in the PBL group. These findings demonstrate that Problem-Based Learning not only improves students' cognitive abilities but also cultivates essential learning dispositions such as independence and creativity. This research provides empirical support for the integration of student-centered learning models in mathematics education to promote higher-order thinking skills.

Keywords: Problem-Based Learning, Learning Independence, Mathematical Creative Thinking

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INTRODUCTION

The learning process is necessary to achieve an education that can improve a person's quality of life. One of the learning activities carried out in schools is mathematics. Mathematics is a compulsory subject for all students as a reference for exploring information using logical, analytical, systematic, critical, innovative, and creative thinking skills (Febrianingsih, 2022; Bütüner et al., 2025; Guohua et al., 2025). In mathematics learning, teachers are required to create a fun learning environment, foster creativity, and achieve learning objectives. Student creativity can grow with encouragement from teachers. One way to do this is by implementing creative and innovative learning models. The context of creativity is often used to uncover creative thinking. During classroom learning, students find it difficult to solve problems if the questions given differ from the examples provided by the teacher. In this case, creative mathematical thinking skills are needed to solve problems.

According to Qomariyah & Subekti (2021), creative thinking in mathematics, also known as divergent thinking, is a mental process that allows a person to generate various alternative answers from available information, focusing on the quantity and relevance of the answers. Similarly, according to Marliani (in Saidah, Dwijanto, 2020), mathematical creative thinking is the skill of generating new ideas or solutions to solve a problem. According to Sumarmo (in Ramdani & Apriansyah, 2018), the components of mathematical creative thinking are:*self-efficacy*, flexibility, skill, awareness, and a sense of dependence. In developing mathematical creative thinking skills, students' learning independence is required. Students who have learning independence will continue to strive to learn so that they gain satisfaction in their learning process. Independence is not only students learning alone without the help of a teacher, but students are trained to take learning initiatives by seeking ideas from various sources and formulating ideas (Lovenia, 2016; Braun et al., 2023). There are several indicators that can be used to measure learning independence, namely: 1) learning initiative, 2) diagnosing learning needs, 3) setting learning targets and goals, 4) monitoring, organizing and controlling learning progress, 5) viewing difficulties as challenges, 6) utilizing and seeking relevant sources, 7) selecting and implementing learning strategies, 8) evaluating the learning process and results and 9) having*self-concept*or self-concept (Ambiyar et al., 2020).

A number of international benchmarks in mathematics show the current learning outcomes of mathematics in schools.Indonesian students' math skills are still low compared to other countries. The objectives of mathematics learning have not been achieved effectively, as evidenced by survey results.*Programme for International Student Assessment* (PISA) in 2022, the mathematics ability of students in Indonesia is still classified as low or below average, with a score of 366 (OECD, 2023). Likewise, the results of the*Trends in International Mathematics and Science Study* (TIMSS) according to Rahmawati in (Wibawa et al., 2023) regarding students' mathematical abilities, Indonesia obtained a mathematics achievement score or*mathematics achievement distribution*as many as 397 with the percentage of students' correct answers for cognitive knowing (*knowing*) by 32%, applying (*applying*) by 24%, and reasoning (*reasoning*) by 20%. This situation places Indonesia as one of the countries with the lowest scores, ranking 45th out of 50 participating countries. The TIMSS results indicate that Indonesian students' mathematical abilities are still low in reasoning, application, and knowledge. Low basic mathematical abilities also mean low higher-order thinking skills, one of which is students' creative mathematical thinking.

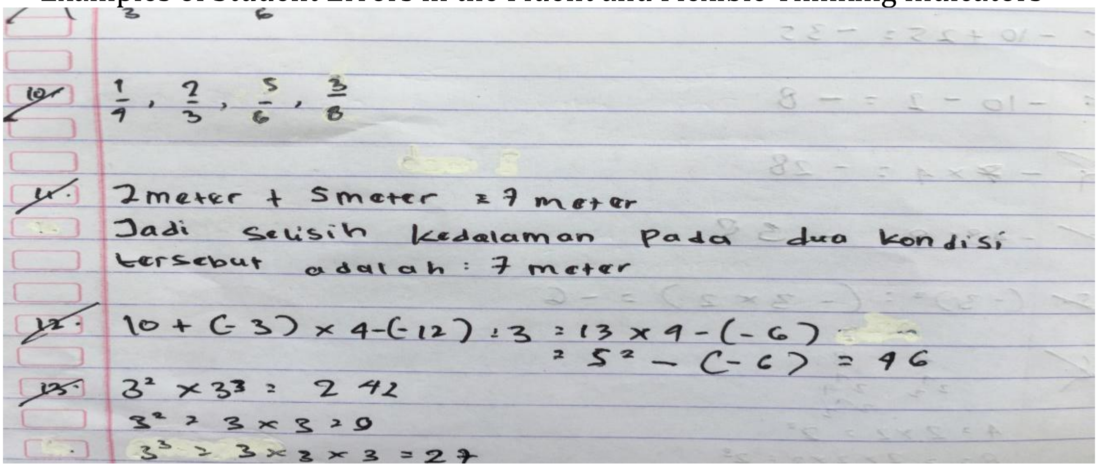
Low mathematical creative thinking skills also occurred at SMP Negeri 2 Mesuji, Lampung. This is evident in the still low results of the daily test on Chapter I, integers, which was tested on 224 seventh-grade students of SMP Negeri 2 Mesuji, Lampung. The average daily test scores are presented in Table 11

Table 1 Average Daily Test Score for Chapter I, Class VII, SMP Negeri 2 Mesuji, Lampung

Class	VII A	VII B	VII C	VII D	VII E	VII F	VII G
Rate-rate	49,25	50,75	51,5	48,5	49,5	49,25	48,75

Judging from the majority of students' answers, it shows that students are not yet able to think fluently in solving problems with the right answers and are not yet able to think flexibly in providing interpretations of a problem. This can be seenfrom the students' answers to one of the daily test questionsCHAPTER I, matter of whole numbers, which includes indicators of mathematical creative thinking ability, namely indicators of fluent thinking and flexible thinking. This question was tested on 224 seventh-grade students of SMP Negeri 2 Mesuji, Lampung. The question is as follows: "An amateur diver first practices diving at a depth of 2 meters below sea level. Then he descends again to a depth of 5 meters below sea level. What is the difference in depth between the two positions?" The following is a sample answer.

Figure 1
Examples of Student Errors in the Fluent and Flexible Thinking Indicators



Students who made similar mistakes as in Figure 1.1 were 48.2% of the total number of students who took the daily test.CHAPTER I, Integer Material. Students are unable to interpret problems correctly, so they cannot solve problems with the correct solution.The question asks for the difference, but the student actually answers by using addition operations.Low ability creative thinking mathematically involved play a role in the low students' mathematics achievement in general. Thinking skills are inseparable from problem-solving ability problem (*problem solving*), Which become a major part in learning mathematics. Low thinking ability creative due to the inaccuracy of the method selection learning. Often learning does not facilitate students to think high level. This result in No students' habits to finish non-routine problems and creative thinking. Ability creative thinking can trained with learning Which nature constructivism.

The problem that happening in the field due to learning by using model conventional ones prioritize*text book oriented* And *teacher centered*. So that results students only pay attention teachers and answers students only fixated on material or the concept that is in the book. With Thus, the ability to think students' creativity and independence in learning are necessary improved in schools by giving opportunity for students to convey what is is on his thoughts. Those questions often given to students in learning are routine questions that must have one correct answer according to the book text or question in accordance with the What which the teacher exemplifies, until make students tend to memorize solutions problem.

Thinking ability creative students are not will be easy to develop if There isn't any stimulus. The stimulus what is meant is motivation strong/great desire to solve problems and the existence of attention from teachers in solving problem. The stimulus done by the teacher can in the form of a gift problem. Problem solving in activities learning will make students are more interested until you can stimulate them for more active. This because inside student learning required to be able to complete problem with doing investigation and independent or group investigations. Application of learning based on the problem can train students creative thinking, analyzing and solve complex problems, as well as work in a cooperative in small group.Thinking ability creative that will be developed in learning includes thinking aspects fluent, thinking flexible, thinking original and thinking elaboration. Efforts to improve thinking creative andstudent learning independence in learning mathematics, one of them can use learning modelstudent-centered. Student-centered learning is learning that involves students actively constructing their own knowledge and developing their potential to the maximum. One of student-centered model is a model *Problem-Based Learning* (PBL).

Based on the results of research conducted by (Rubiyanti et al., 2020), the results of the study show that the application of the model*Problem-Based Learning*can improve students' learning independence. Meanwhile, some research revealed that PBL can improve students' mathematical creative thinking skills better than conventional learning approaches (Umam et al. 2021; afandy et al, 2025; Bulut Ates, & Akmatis, 2024. In line with this, research conducted by Erni et al. (2022) showed an effect of learning independence on students' mathematical creative thinking skills. think creatively. Where student independence is in the moderate category and students' creative thinking abilities are in the fairly creative category. Based on the results of several previous studies, it can be concluded that the learning model*Problem-Based Learning*provide a positive influence on students' learning independence and mathematical creative thinking abilities.

The PBL model has orientation stages, organization, investigation, presentation, analysis and evaluation that will help students in search and find own material or learned answers according to the problem given (Guohua et al., 2025; Ritala et al., 2024; Jaakkola et al., 2024). Until creative thinking aspects students who are still weak can increase, as well as train students' learning independence. By therefore, in learning students are required to be able to think creatively and independently in looking for answers and other informationrelated to the material Which studied.Based on the description above, the model*Problem-Based Learning*considered capable of improving learning independence and abilitythink creative students. This sparked interest in conducting similar research. This research differs from previous research. The difference between this research and previous research is that the purpose of this research is not only to determine the influence of the learning model*Problem-Based Learning* to learning independence and abilitythink creativestudents, but also to determine the effectiveness of the model*Problem-Based Learning*reviewed from learning independence and abilitythink creativestudents. This study was conducted with the aim of answering two problem formulations, namely: (1) Is the Problem-Based Learning model effective in increasing students' learning independence compared to conventional learning? and (2) Is the Problem-Based Learning model effective in increasing students' mathematical creative thinking skills compared to conventional learning? In line with these formulations, the aim of this study is to examine the effectiveness of the Problem-Based Learning model on learning independence and mathematical creative thinking skills of class VII students of SMP Negeri 2 Mesuji, Lampung.

METHOD

This study used a quasi-experimental study with a pretest-posttest control group design. In this study, there was one independent variable, namely the Problem Based Learning (PBL) learning model, and two dependent variables, namely students' learning independence and mathematical creative thinking abilities. The population in this study was all 7th grade students of SMP Negeri 2 Mesuji, Lampung, totaling 224 students and spread across seven classes. The research sample was determined using a cluster random sampling technique, namely selecting class VII.F as the experimental class and class VII.G as the control class, each consisting of 32 students. The experimental class received learning with the Problem-Based Learning model, while the control class received conventional learning. Data collection techniques were carried out using two types of instruments. First, a descriptive test to measure mathematical creative thinking abilities given before (pretest) and after (posttest) the treatment. Second, a learning independence questionnaire compiled based on indicators of student learning independence. Both instruments have gone through a content validation process by experts and reliability testing before being used in data collection. Data analysis began by calculating the gain score (N-Gain) to assess the improvement in student learning outcomes after treatment. Next, a normality test was performed using the t-test.*Kolmogorov-Smirnov*to ensure data distribution, as well as testing the homogeneity of variance with the test*Levene*to determine the similarity of variance between the experimental and control groups. To test the differences in the effectiveness of the learning model,*independent t-test*on gain and posttest scores. Furthermore, a one-tailed proportion test was used to determine whether the proportion of students achieving the "good" category for independent learning and mathematical creative thinking skills exceeded 60%. All analyses were conducted using statistical software to improve the accuracy of the research results.

RESULT AND DISCUSSION

Data on students' initial learning independence was obtained from the results*pretest*. Result data*pretest* were analyzed to determine whether students who participated in learning with the learning model*problem-based learning* have the same or different initial learning independence as students who follow conventional learning. Data on the initial learning independence of the experimental and control classes are presented in Table 2

Table 2
Data on Students' Initial Learnng Independence

Class	Number of Students	Rate-rate	Standard Deviation	Variance	Lowest Score	Highest Score
Experiment	32	89,44	5,83	34	78	100
Control	32	87,72	8,27	68,40	71	105

Based on Table 2, the average initial learning independence of students in the experimental class was higher than that of the control class by a difference of 1.72, and had a lower standard deviation and variance of 2.44 and 34.4, respectively, indicating that the distribution of scores in the experimental class was more homogeneous. The lowest score in the experimental class was also higher than that of the control class by a difference of 7, but the highest score was lower by a difference of 5. However, the results of the difference test showed that t_{count}(0.96) is smaller than t_{table}(1.67), so H0 is accepted, which means there is no significant difference in the average initial learning independence of students between problem-based learning and conventional learning models. Final student learning independence data was obtained from the results*posttest* which was carried out at the end of the meeting. The final learning independence data for both classes are presented in Table 3

Table 3
Final Student Learning Independence Data

Class	Number of Students	Rate-rate	Standard Deviation	Variance	Lowest Score	Highest Score
Experiment	32	100,41	6,04	36,44	90	112
Control	32	93,31	7,69	59,19	82	109

Based on Table 3 the average final learning independence of students in the experimental class was higher than the control class by a difference of 7.1, accompanied by a lower standard deviation and variance of 1.65 and 22.75, respectively, indicating that the distribution of scores in the experimental class was more homogeneous. In addition, the lowest and highest scores of students in the experimental class were also higher than those in the control class, by a difference of 8 and 3 points, respectively. Analysis of the increase in students' learning independence scores was conducted to determine whether the increase in students' learning independence who participated in learning with the learning model*problem-based learning* higher or equal to the increase in learning independence of students who follow conventional learning. The calculation of the increase in score is obtained from the difference between the scores*posttest*and score*pretest* then divided by the difference between the maximum score and the score*pretest*. After the calculations were carried out, the data obtained*gain*in the experimental and control classes presented in Table 3

Table 4
Data *Gain* Student Learning Independence

Class	Number of Students	Rate-rate	Standard Deviation	Variance	*Gain* The lowest	*Gain* Highest
Experiment	32	0,353	0,180	0,032	0,00	0,66
Control	32	0,174	0,126	0,016	0,00	0,40

Based on Table 4, the average gain in learning independence of students in the experimental class was higher than that of the control class by a difference of 0.179. However, the standard deviation and variance of the experimental class were also higher by 0.054 and 0.016, respectively, indicating that the gain data in the experimental class was more heterogeneous. The lowest gain for both classes was the same, namely 0.00, but the highest gain in the experimental class was higher than the control class by a difference of 0.26.

Results of the first hypothesis testdata *gain*independent learningstudents who participate in learning with the model*problem-based learning*and conventional learningobtained$t_{hitung} = 4,39 t_{hitung} = 4,39$and from the distribution list$t$obtained$t_{tabel} = t_{0,95(62)} = 1,67 t_{tabel} = t_{0,95(62)} = 1,67$. $t_{hitung} = 4,39 t_{hitung} = 4,39 > t_{tabel} = 1,67 t_{tabel} = 1,67$ face H_0rejected. Thus, the average data*gain*learning independence of students who participate in learning with the model*problem-based learning*higher than the average data*gain*learning independence of students who follow conventional learning.Based on the results of the normality test, the final learning independence data for students in the experimental class comes from a normally distributed population so that the second hypothesis test uses a one-sided proportion test. Based on the analysis results obtained$z_{hitung} = 2,08 z_{hitung} = 2,08$and from the distribution list*With*obtained$z_{tabel} = z_{0,45} = 0,1645 z_{tabel} = z_{0,45} = 0,1645$. $z_{hitung} = 2,08$ $z_{hitung} = 2,08 > z_{tabel} = z_{tabel} =$ 0.1645 eye H_0rejected. Thus,the proportion of students who have learning independence in the good category after participating in learning with the learning model*problem-based learning*more than 60% of the number of students in that class. . Thus, more than 60% of students in the class have good category of learning independence after participating in learning with the Problem-Based Learning model.

The analysis of each indicator of student learning independence aims to determine the achievement of each indicator. The analysis of each indicator is conducted on score data.*pretest* and score*posttest* in the experimental class and the control class. The results of the analysis of each learning independence indicator are presented in Table 5

Table 5
Achievement of Student Learning Independence Indicators

No	Indicator	Early (%)		End (%)	
		Experiment	Control	Experiment	Control
1	Learning initiatives	64,84	66,31	80,86	75,29
2	Diagnosing learning needs	77,73	79,30	85,03	81,51
3	Setting learning goals	76,88	73,13	84,53	77,19
4	Selecting and using learning resources	79,30	75,39	84,38	78,91
5	View difficulties as challenges	86,33	78,52	86,33	80,86
6	Selecting and implementing learning strategies	76,17	73,44	82,81	75,78
7	Collaborate with others	76,56	76,17	84,38	80,08
8	Control yourself	76,56	71,35	84,90	74,74
Rate-rate		76,80	74,20	84,15	78,04

Based on Table 5, the average initial and final achievement of the learning independence indicator for students in the experimental class was higher than that of the control class, with differences of 2.60 and 6.11, respectively. Both classes experienced an increase, namely 7.35% in the experimental class and 3.84% in the control class, which indicates that the increase in achievement of the learning independence indicator was greater in the experimental class. Thus, it can be concluded that the problem-based learning model is more effective in improving student learning independence than conventional learning.Data creative thinking skillsstudents' initial mathematical results are obtained from the results*pretest*. Result data*pretest* were analyzed to determine whether students who participated in learning with the learning model*problem-based learning* own creative thinking skillsinitial mathematical values that are the same or different fromcreative thinking skillsinitial mathematical abilities of students who follow conventional learning

Table 6
Data on Students' Initial Mathematical Creative Thinking Ability

Class	Number of Students	Rate-rate	Standard Deviation	Variance	Lowest Score	Highest Score
Experiment	32	9,31	3,35	11,19	2	14
Control	32	9,31	2,86	8,16	4	13

Based on Table 6, the average initial mathematical creative thinking ability of students in the experimental and control classes is the same, namely 9.31, but the standard deviation and variance of the experimental class are higher, with a difference of 0.45 and 3.03, respectively, which indicates that the distribution of scores in the control class is more homogeneous. The lowest score in the experimental class is lower, while the highest score is higher than the control class. The results of the difference test show t_count = 0.00 < t_table = 1.67, so H0 is accepted and it can be concluded that there is no difference in the average initial mathematical creative thinking ability between students who participated in problem-based learning and conventional learning. Data on students' final mathematical creative thinking ability was obtained from the results*posttest* which was carried out at the end of the meeting. The final mathematical creative thinking ability data for both classes is presented in Table 7

Table 7
Final Mathematical Creative Thinking Ability Data of Students

Class	Number of Students	Rate-rate	Standard Deviation	Variance	Lowest Score	Highest Score
Experiment	32	36,75	5,61	31,42	24	44
Control	32	31,78	5,49	31,11	24	40

Based on Table 7, the average final mathematical creative thinking ability of the experimental class students was higher than the control class with a difference of 4.97, although the standard deviation and variance were also higher at 0.12 and 1.31 respectively, which indicates a more homogeneous distribution of the control class scores. The lowest score of both classes was the same, namely 24, but the highest score of the experimental class students was higher than the control class with a difference of 4. The calculation of the increase in scores was obtained from the difference between the scores*posttest*and score*pretest* then divided by the difference between the maximum score and the score*pretest*. After the calculations were carried out, the data obtained*gain*in the experimental and control classes presented in Table 7.

Table 8
Data *Gain* Students' Mathematical Creative Thinking Ability

Class	Number of Students	Rate-rate	Standard Deviation	Variance	*Gain* The lowest	*Gain* Highest
Experiment	32	0,798	0,147	0,022	0,429	1
Control	32	0,656	0,133	0,018	0,444	0,875

Based on Table 8, the average data*gain*The mathematical creative thinking ability of experimental class students is higher than the average data*gain*The mathematical creative thinking ability of students in the control class with an average difference of 0.142 between the two classes. The standard deviation of the experimental class higher than the standard deviation of the control class with a difference in standard deviations between the two classes, namely 0.014. This shows that the data*gain* the experimental class is more heterogeneous than the data *gain*control class. The variance of the experimental class is higher than the variance of the control class with a difference in variance between the two classes of 0.004.*Gain*the lowest score obtained by students in the experimental class was lower than*gain*the lowest obtained by students in the control class with a difference*gain*the second lowest class, namely 0.015.*Gain*the highest score obtained by students in the experimental class was higher than*gain*the highest obtained by students in the control class with a difference*gain*the second highest class, namely 0.125. Results of the first hypothesis test data*gain*mathematical creative thinking abilities of students who participate in learning with the model*problem-based learning*and conventional learning is obtained$t_{hitung} = 4,2$ $t_{hitung} = 4,2$and from the distribution list*t*obtained$t_{tabel} = t_{0,95(62)} = 1,67$ $t_{tabel} = t_{0,95(62)} = 1,67$. $t_{hitung} = 4,2t_{hitung} = 4,2$ > $t_{tabel} = 1,67t_{tabel} = 1,67$ face H_0rejected. Thus, the average data*gain*mathematical creative thinking abilities of students who participate in learning with the model*problem-based learning*higher than the average data*gain*mathematical creative thinking abilities of students who follow conventional learning. Based on the results of the normality test, the final mathematical creative thinking ability data of students in the experimental class comes from a normally distributed population so that the second hypothesis test uses a one-sided proportion test. Based on the analysis results obtained $z_{hitung} = 2,80z_{hitung} = 2,80$and from the distribution list*With*obtained $z_{tabel} = z_{0,45} = 0,1645z_{tabel} = z_{0,45} = 0,1645$. $z_{hitung} = 2,80z_{hitung} = 2,80$ > $z_{tabel} = z_{tabel} =$ 0.1645 eye H_0rejected. Thus, the proportion of students who have good mathematical creative thinking skills after participating in learning with the learning model*problem-based learning*more than 60% of the number of students in that class.

The analysis of each indicator of students' mathematical creative thinking ability aims to determine the achievement of each indicator. The analysis of each indicator is conducted on the score data.*pretest* and score*posttest* in the experimental class and the control class. The results of the analysis of each indicator of mathematical creative thinking ability are presented in Table 4.8.

Table 9
Achievement of Students' Mathematical Creative Thinking Ability Indicators

No	Indicator	Early (%)		End (%)	
		Experiment	Control	Experiment	Control
1	Provide correct answers or ideas to the questions asked	22,66	22,19	83,75	72,50
2	Produces varied answers with different points of view	19,53	19,53	82,03	69,53
3	Can provide answers according to his own thoughts	19,53	20,70	82,42	71,48
4	Can detail an idea or answer so that it is clearer	20,31	20,31	84,38	73,18
Rate-rate		20,51	20,68	83,14	71,67

Based on Table 9, the average initial achievement of the mathematical creative thinking ability indicator of students in the experimental class was lower than the control class by 0.17, but the final achievement was higher by 11.47. Both classes experienced an increase, namely 62.63% in the experimental class and 50.99% in the control class, indicating that the increase in the experimental class was higher. Thus, it can be concluded that learning with a problem-based learning model is more effective in improving students' mathematical creative thinking abilities than conventional learning.

DISCUSSION

The main results of this study indicate that the Problem-Based Learning (PBL) learning model is significantly effective in improving two aspects of learning, namely students' learning independence and mathematical creative thinking skills. In the aspect of learning independence, data obtained showed that the proportion of students who achieved the "good" category after participating in learning with the PBL model reached 71.88%. This indicates a high level of independence because it is able to encourage more than 60% of students to be more active, independent, and responsible in the learning process. Meanwhile, the aspect of mathematical creative thinking skills shows that there is a significant difference between the experimental class and the control class. The results of statistical tests show that the average posttest score of students in the experimental class experienced a higher increase than the control class. The results of the N-Gain calculation show that the increase in students' creative thinking skills in the experimental class is in the medium to high category, while the control class tends to be in the low category. Creative thinking indicators such as fluency, flexibility, originality, and elaboration experienced a more dominant increase in the experimental class. These findings indicate that the Problem-Based Learning model has a positive impact on learning outcomes and has a direct influence on the development of higher-order thinking skills and independent learning attitudes. Thus, PBL can be an effective alternative learning strategy to improve the quality of mathematics learning in junior high school.

The first hypothesis test in this study aims to measure the effectiveness of the Problem-Based Learning (PBL) model in improving student learning independence. Data were collected through a learning independence questionnaire before and after the implementation of the PBL model, then analyzed using a t-test on the gain value. The analysis results showed a significant increase in student learning independence (p-value <0.05), so the null hypothesis was rejected and the alternative hypothesis was accepted. This proves that the implementation of the PBL model is effective in improving learning independence. These findings align with previous research, such as that conducted by Priwitasari et al., 2021, which found that the PBL model can improve students' independence and problem-solving skills, especially when combined with Computer-Based Testing. The characteristic of PBL, which gives students direct responsibility for solving problems, helps them develop initiative and self-evaluation skills. These results are also supported by Taufiq Syarifudin et al., 2020, who found that implementing PBL with metacognitive strategies can improve students' critical thinking and self-reflection skills. Theoretically, these research findings support the view that learning independence is an important indicator of student-centered learning. PBL encourages students to actively explore and analyze information through contextual problem-solving, as well as develop responsibility for their own learning process. Therefore, the implementation of this model is not only statistically effective but also has a strong theoretical basis for developing independent and sustainable learning characteristics.

The first hypothesis test in the aspect of mathematical creative thinking skills aims to determine the effectiveness of the Problem-Based Learning (PBL) model. Data were collected through pretests and posttests after implementing the model, then analyzed using gain calculations and t-tests. The results showed that the average gain of the experimental class was significantly higher than that of the control class (p-value <0.05). This finding confirms that the PBL model is more effective in improving students' mathematical creative thinking skills compared to conventional learning. Conceptually, the PBL model encourages students to face contextual problems through the stages of exploration, investigation, and reflection. This process stimulates students to use non-routine thinking strategies, generate new ideas, and produce original and flexible solutions. Thus, PBL actively hones indicators of creative thinking skills such as fluency, flexibility, uniqueness, and decomposition. This is also supported by research (Ngadha et al., 2024) and (Saputri et al., 2023) which show that PBL can increase creativity in solving mathematical problems. Theoretically, the success of the PBL model aligns with the social constructivism approach, where students construct knowledge through active interactions with their environment and peers. In problem-based learning, students are challenged to explore various possible solutions and engage in collaborative discussions, which stimulates the development of creative thinking. Thus, PBL is not only statistically proven but also theoretically effective in encouraging students to think more broadly, deeply, and innovatively in mathematics learning.

The second hypothesis test aims to determine whether more than 60% of students in the experimental class who followed the Problem-Based Learning (PBL) learning model have learning independence in the good category. The results of data processing show that the proportion of experimental class students who have learning independence in the good category exceeds 60%. Using a one-sample proportion test, a p-value smaller than 0.05 indicates that the null hypothesis (H_0) is rejected, and the alternative hypothesis (H_1) is accepted. This means that it is statistically proven that more than 60% of experimental class students show a good level of learning independence after participating in learning with the PBL model. These results indicate that the PBL model can encourage independence in students' learning. In PBL, students are actively involved in identifying, planning, and solving real-life problems, requiring them to manage their time, take initiative, and evaluate their learning progress. These activities reflect strong indicators of independent learning. Previous research also supports these findings, as demonstrated by (Priwitasari et al., 2021) and (Aprila & Fajar, 2022), which stated that PBL can train students to learn independently, take responsibility for their assignments, and take initiative in solving problems without relying on teacher instructions. Theoretically, PBL aligns with the principles of constructivist learning, where students construct their knowledge through experience and reflection on learning activities. In this model, students play an active role as learning subjects, giving them control over the learning process. This contributes to the development of self-regulated learning, which is essential in 21st-century education. Based on the results of the proportion test and support from previous research, it can be concluded that PBL has proven effective in increasing student learning independence and can be an alternative learning method that shapes independent learning characteristics.

Based on the results of post-test data processing of creative thinking skills, more than 60% of students in the experimental class using the Problem-Based Learning (PBL) learning model were categorized as having "good" to "very good" creative thinking skills. In contrast, the proportion of students with similar categories in the control class was below 60%. The one-sample proportion test showed that the p-value was below 0.05, leading to the rejection of the null hypothesis (H_0) and the acceptance of the alternative hypothesis (H_1). This indicates that statistically, more than 60% of students in the experimental class had good creative thinking skills. These results confirm that PBL has a positive effect on students' mathematical creative thinking skills. PBL's characteristics, which prioritize open-ended problem solving, collaboration, idea exploration, and reflection, are crucial for developing creative thinking. Students are involved in the process of analyzing contextual problems and developing solution strategies, encouraging the emergence of new ideas and innovative approaches to mathematical problems. This is consistent with research findings from Ngadha et al., 2024 and Saputri et al., 2023, which indicate that PBL can enhance students' creative thinking in mathematics learning. Theoretically, PBL aligns with constructivist and humanistic approaches that encourage students to become independent and innovative thinkers. According to Guilford (1967) in (Heriyanto et al., 2020), creative thinking involves divergent thinking skills, flexibility, originality, and elaboration, which can develop in a learning environment that supports open exploration, such as the PBL model. Based on the results of the proportion test, support from previous research, and existing theories, it can be concluded that PBL is effective in improving students' creative thinking skills, making it a strategic approach to fostering higher-order thinking competencies among students.

Analysis of the achievement of learning independence indicators shows that students in the experimental class who participated in learning with the Problem-Based Learning (PBL) model experienced a more significant increase compared to the control class. The overall average learning independence indicator in the experimental class increased from 76.80% to 84.15%, while in the control class it only increased from 74.20% to 78.04%. The largest increase was seen in the learning initiative indicator, where the experimental class increased by 16.02%, compared to only 8.98% in the control class. In addition, increases also occurred in the indicators for diagnosing learning needs (7.3% in the experimental class vs. 2.21% in the control class) and setting learning goals (7.65% in the experimental class vs. 4.06% in the control class), indicating that PBL students were more active and independent in identifying deficiencies, setting goals, and exploring information. Students in the experimental class also maintained a positive attitude towards challenges, with the indicator for viewing difficulties as challenges remaining high (86.33%). Overall, PBL is effective in building students' learning independence by encouraging their active role in planning, implementing, and self-evaluating learning. Analysis of the achievement of indicators of mathematical creative thinking skills shows that the Problem-Based Learning (PBL) learning model has a significant positive impact on improving students' thinking skills, especially in the experimental class. The average ability of students in the experimental class increased sharply from 20.51% to 83.14%, while the control class only increased from 20.68% to 71.67%. The largest increase occurred in the indicators of providing correct answers (from 22.66% to 83.75%) and producing varied answers (from 19.53% to 82.03%) in the experimental class. In addition, students' ability to provide answers based on their own thoughts also increased rapidly in the experimental class (from 19.53% to 82.42%). A significant increase was also seen in the ability to detail ideas clearly, from 20.31% to 84.38% in the experimental class. These findings indicate that PBL is effective in increasing students' activeness, accuracy, and creativity in solving mathematical problems, as well as encouraging exploration of ideas and reflection. Research (Saputri et al., 2023) supports this finding by stating that PBL improves students' critical thinking and mathematical communication skills through interactive and student-centered learning activities.

This research contributes to the development of mathematics education by implementing the Problem-Based Learning (PBL) model to improve students' learning independence and mathematical creative thinking skills. The novelty of this research lies in its evaluative approach, which measures the influence and effectiveness of the PBL model through simultaneous proportion and comparison analysis of two variables. Unlike previous research that tends to assess one aspect of learning outcomes, this research shows that PBL can foster an independent attitude in learning while simultaneously developing students' creative thinking in solving mathematical problems. Practically, the research results can be used as a guide for teachers to apply the problem-based learning model as an alternative strategy to improve the quality of classroom learning. Academically, the research results expand the study of the relationship between innovative learning approaches and students' soft skills, such as independence and creativity. Policy-wise, the research results can provide input for educational policymakers at the school level and education offices in designing teacher training and curricula that support active learning in mathematics.

This study has several limitations in terms of context, duration, and data collection. First, the study only involved two classes from one school, namely SMP Negeri 2 Mesuji, Lampung. This causes the generalization of the findings to be limited to the context and characteristics of the students involved. Second, the duration of the learning implementation using the Problem-Based Learning model was carried out for a relatively short period, so the long-term impact of the model on the development of independent learning and creative thinking skills cannot be determined. Third, the measurement of creative thinking skills and independent learning was carried out using test instruments and questionnaires that still have the possibility of subjective bias from student responses. On the other hand, external factors such as the role of the teacher, the learning environment, and student readiness in problem-based learning (PBL) were not fully controlled, which affected the effectiveness of PBL implementation.

Based on the findings and limitations of this study, several recommendations are provided for further research. First, it is recommended that similar research be conducted at different educational levels, such as elementary or high schools, to assess the consistent effectiveness of the Problem-Based Learning (PBL) model in enhancing learning independence and creative thinking skills across different ages and levels of material complexity. Second, for theoretical development, further studies can integrate the PBL model with other learning approaches, such as project-based or STEM (Science, Technology, Engineering, and Mathematics) approaches, to test the synergistic effects on students' cognitive and affective aspects. Third, in terms of implementation in the field, teachers and schools are expected to be more active in adopting learning models that emphasize active student involvement, by providing systematic training to teachers to enable them to design and implement PBL effectively. Furthermore, schools and educational policymakers are also expected to support the use of innovative learning models such as PBL through curriculum policies and the provision of adequate supporting facilities.

CONCLUSION

The findings of this study indicate that students engaged in learning through the Problem-Based Learning (PBL) model demonstrated significantly greater improvements in independent learning and creative mathematical thinking skills compared to those receiving conventional instruction. Problem-Based Learning not only serves as an effective pedagogical strategy in encouraging independent learning but also in cultivating essential higher-order thinking skills in mathematics. Interactive, student-centered Problem-Based Learning encourages students to actively explore, investigate, and construct knowledge, thereby strengthening both the cognitive and affective domains of learning. Students who achieved the “high” category in independent learning and creative mathematical thinking after participating in the Problem-Based Learning approach exceeded 60% of the class population. This substantial percentage indicates that Problem-Based Learning has the potential to positively change classroom learning dynamics by promoting deeper engagement and sustained intellectual curiosity among students. These results underscore the relevance of implementing Problem-Based Learning more broadly, particularly in mathematics education, to support the development of independent and creatively competent learners aligned with the demands of 21st-century education.

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