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Comparing Improvements in Students' Mathematical Creative Thinking Skills Between Problem-Based Learning and Inquiry-Based Learning

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ABSTRACT

Developing students' mathematical creative thinking skills is important because these skills enable them to generate alternative solutions to problems. However, interviews with mathematics teachers at SMP Negeri 2 Cilegon indicated that students struggled to explore ideas and develop problem-solving strategies independently. This study aimed to compare students' mathematical creative thinking skills and improvements in these skills following problem-based learning (PBL) and inquiry-based learning (IBL). A quantitative, quasi-experimental study was conducted using a nonequivalent pretest–posttest comparison-group design. The sample comprised 70 seventh-grade students selected through cluster random sampling: 35 students from Class VII B formed the PBL group, and 35 students from Class VII J formed the IBL group. Both groups received four instructional sessions on plane figures. Data were collected using a mathematical creative thinking test, an observation sheet, and a student response questionnaire. The test comprised four constructed-response items assessing fluency, flexibility, originality, and elaboration. All test items were reported as valid, with validity coefficients ranging from 0.74181 to 0.79536, and the test demonstrated internal consistency, with a Cronbach's alpha of 0.767. Data analysis included normality and homogeneity tests, an independent-samples t-test, and normalized gain (N-gain) calculations. The mean posttest scores were 82.77 for the PBL group and 76.63 for the IBL group, while the corresponding mean N-gain values were 0.77 and 0.69. The independent-samples t-test indicated a statistically significant between-group difference, $t(68) = 3.761$, $p < .001$. Overall, the PBL group achieved higher mean posttest scores and greater mean normalized gains than the IBL group. These findings suggest that PBL is a promising instructional approach for supporting students' mathematical creative thinking in the context studied.

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Introduction

Education is a crucial aspect of improving the quality of human resources and serves as a means to develop students' potential so they can face life's various challenges. As we enter the 21st century, education is no longer focused solely on the acquisition of knowledge but is also directed toward the development of higher-order thinking skills, which include critical thinking, creativity, communication, and collaboration. This paradigm shift calls for a learning process that can provide meaningful learning experiences so that students not only understand concepts but are also able to apply their knowledge to effectively solve various problems. In line with these requirements, the implementation of the Merdeka Curriculum in Indonesia emphasizes student-centered learning to develop 21st-century skills through an active, contextual learning process that is oriented toward the optimal development of students' potential (Sani, Abdullah, 2020). According to Sulistyaningrum et al., (2023), education serves not only as a process of knowledge transfer but also as an effort to guide students so they can fully develop their potential as individuals and as members of society.

One of the competencies that needs to be developed in 21st-century learning is the ability to think creatively. This ability is an important foundation for students to generate new ideas, view problems from various perspectives, and find effective solutions. In mathematics education, creative thinking plays a very important role because mathematics not only requires students to arrive at the correct answer but also encourages them to discover a variety of logical, flexible, and original problem-solving strategies. Therefore, mathematics instruction should create a learning environment that provides students with opportunities to explore ideas, express their opinions, and build their own knowledge to the fullest extent possible (Handayani, 2023). Taqwim & Huda (2024) also state that creative thinking skills are one of the competencies that need to be developed in the "Merdeka" curriculum because they help students tackle the learning challenges of the 21st century.

Although creative mathematical thinking plays an important role in mathematics learning, various studies show that this ability has not yet developed to its full potential. Faelasofi (2021), states that students' mathematical creative thinking skills—particularly in the areas of fluency, flexibility, and elaboration—remain at a low level. Trisna Rukhmana (2022) also noted that students still tend to solve problems based on examples provided by the teacher, so they have difficulty when faced with problems of a different format. This situation indicates that most students still have difficulty generating various alternative solutions or developing their ideas in detail when solving a math problem. The findings of Hanifah et al., (2024), also indicate that low levels of creative thinking are influenced by a learning process that remains teacher-dominated, the use of learning models that lack variety, and students' tendency to follow the solution procedures demonstrated to them without trying other strategies. According to Utami (2020), teaching that is too teacher-centered results in students having fewer opportunities to explore ideas and develop creative thinking skills. As a result, mathematics instruction is more focused on arriving at the final answer than on the thought process that fosters students' creativity.

This issue was also identified at Cilegon City Public Junior High School No. 2, based on an interview with a 7th-grade mathematics teacher. The teacher noted that students still struggle when working on problems that require more than one solution or call for ideas different from the examples provided. During the learning process, students tend to wait for the teacher's explanation and are not accustomed to expressing their opinions or discovering concepts on their own. This situation is supported by the results of a preliminary test of mathematical

creative thinking skills administered to the 70 students who were the subjects of this study. The average pretest score for the PBL group was 23.54, while that for the IBL group was 24.11. The difference in initial average scores was 0.57 points, and the results of the t-test showed a p-value of 0.664 (>0.05), indicating that the initial abilities of the two groups were relatively equivalent. The data provide a quantitative picture of the initial level of students' mathematical creative thinking skills and serve as a basis for assessing improvements in these skills after both groups were exposed to different instructional models. The results indicate that students' mathematical creative thinking skills still need to be improved through the implementation of instructional models that actively engage students in constructing their own knowledge.

Given these various challenges, there is a need for an innovative approach to learning that can foster a more active and meaningful learning process and provide students with opportunities to develop ideas and discover concepts on their own. The implementation of a student-centered learning model is seen as one alternative that can support the achievement of these goals. Two learning models considered relevant for developing creative mathematical thinking skills are Problem-Based Learning (PBL) and Inquiry-Based Learning (IBL). Both models are based on constructivism, which positions students as active participants in the learning process. Anggraini et al., (2020) explain that learning that actively engages students can help them build knowledge through the learning experiences gained during the learning process.

The PBL model is a learning model that begins the learning process by presenting contextual problems, thereby encouraging students to analyze the problems, discuss them, and actively find solutions (Maryati & Monica, 2021). Through these contextual problems, students are encouraged to actively engage in the learning process so that they can build their knowledge through meaningful learning experiences (Yusita et al., 2021). In addition, the stages of PBL provide students with opportunities to discuss, seek information, propose various ideas, and develop solutions independently, so that the learning process is oriented not only toward results but also toward the students' thought processes (Nasution, n. R., & surya, 2021). Conceptually, the characteristics of PBL are linked to the four indicators of creative mathematical thinking. Activities that involve generating multiple alternative solutions can foster fluency; the use of different strategies can develop flexibility; the emergence of unconventional solutions can foster originality; and activities that involve explaining and elaborating on solutions in detail can foster elaboration. A recent meta-analysis at the junior high school level also shows that PBL has a positive impact on students' ability to think creatively in mathematics (Waluya & Susilo, 2025).

Meanwhile, the IBL model is a learning model that emphasizes the process of exploring and discovering concepts through systematic inquiry, so that students acquire knowledge based on their own findings (Irfan Supriatna, Wahyudin, 2023). In practice, teachers act as facilitators who guide the inquiry process, while students are given the opportunity to analyze what they have learned and draw their own conclusions about the concepts (Pujiastuti & Haryadi, 2024). Through these inquiry-based activities, students are encouraged to observe, ask questions, gather information, and draw conclusions based on their findings (Yofamella & Taufik, 2023). This inquiry-based process also helps develop logical, critical, creative, and analytical thinking skills in solving various mathematical problems (Sukmawati et al., 2023). The characteristics of IBL are also conceptually linked to the four indicators of creative mathematical thinking. Asking questions and formulating conjectures can foster fluency; exploring various possibilities during an investigation can develop flexibility; discovering different approaches or solutions can foster originality; and describing the results of an investigation and drawing detailed

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
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conclusions can foster elaboration. A study by Waluya & Susilo, (2025) of middle school students using IBL-based e-modules on the topic of flat-sided three-dimensional shapes also reported improvements in four indicators of creative thinking, with an average N-Gain of 0.79.

Given these characteristics, both learning models are considered to have the potential to enhance students' creative mathematical thinking skills because they provide students with opportunities to explore various ideas, develop problem-solving strategies, and build understanding independently. However, PBL and IBL place different emphases on learning activities. PBL positions problems as the primary catalyst for analyzing and developing solutions, whereas IBL places the processes of asking questions, investigating, discovering, and drawing conclusions at the core of learning. Theoretically, these differences in characteristics can lead to distinct learning experiences in developing fluency, flexibility, originality, and elaboration. Therefore, comparing the two models within the same context is important for obtaining empirical evidence regarding differences in the improvement of mathematical creative thinking skills.

A number of studies have examined the application of PBL and IBL on creative thinking skills, but these studies have different characteristics. Studies on PBL among middle school students generally use experimental or quasi-experimental designs with a comparison group involving conventional instruction, whereas studies on IBL often employ development research or compare IBL with other instructional models. Selfiani et al., (2022) concluded that the study of junior high school students showed an improvement in mathematical creative thinking skills using the PBL model. A study by Pujiastuti et al., (2021) showed that inquiry-based learning can improve students' mathematical abilities through their active involvement in the process of inquiry and knowledge construction In line with these findings, another study conducted by Siregar (2024) also reported that the implementation of Inquiry-Based Learning has a positive effect on improving students' mathematical creative thinking skills. These findings demonstrate the potential of PBL and IBL; however, the grade level, subject matter, sample size, research design, and type of intervention differ from those in this study. Thus, previous studies have not specifically provided a direct comparison of PBL and IBL among junior high school students using geometric shapes as the subject matter, involving two groups that both received active learning instruction, and measuring mathematical creative thinking skills based on the indicators of fluency, flexibility, originality, and elaboration. This gap in the literature served as the basis for conducting this study. Based on the above discussion, this study aims to compare the mathematical creative thinking abilities and improvements of students who were taught using the Problem-Based Learning (PBL) and Inquiry-Based Learning (IBL) models in the area of plane figures.

Method

Type of Research

This study employed a quantitative approach using a quasi-experimental design, specifically a nonequivalent pretest-posttest comparison group design. This design was chosen because the researcher could not control all external variables affecting the study's implementation, yet it still allowed for a comparison of changes in students' mathematical creative thinking abilities between the two groups that received different instructional models. The researchers involved two experimental classes. Experimental Class 1 was taught using the Problem-Based Learning (PBL) model, while Experimental Class 2 was taught using the

Inquiry-Based Learning (IBL) model. Before the interventions were implemented, both classes took a pretest to assess the students' initial mathematical creative thinking abilities. After the entire learning sequence was completed, both classes took a posttest to assess the students' final proficiency following the intervention. The nonequivalent pretest-posttest comparison group design used in this study is presented in the Table 1.

Table 1. Research Design

Group	Pre-test	Treatment	Post-test
Experiment 1	O_1	X_1	O_3
Experiment 2	O_2	X_2	O_4

Notes:
O1 : Pretest in experimental class A
O2 : Pretest in experimental class B
O3 : Posttest in experimental class A
O4 : Posttest in experimental class B
X1 : Implementation of the Problem-Based Learning (PBL) model
X2 : Implementation of the Inquiry-Based Learning (IBL) model

Population and Sample

This study was conducted at SMP Negeri 2 in Cilegon during the 2025–2026 school year. The study population consisted of all seventh-grade students in 10 classes. Cluster random sampling was used because the sampling was based on existing class groups; thus, the sample was selected at the class level rather than at the individual level (Nidia Suriani, Risnita, 2023). The sample was selected at random by drawing lots from all seventh-grade classes to select two classes as the research sample. Based on the results of the drawing, seventh-grade classes VII B and VII J were selected as the research sample. Next, the treatment assignment was determined by another random draw to assign students to learning groups, resulting in Class VII B being assigned to the PBL group and Class VII J to the IBL group. The research sample consisted of two classes, each with 35 students, for a total sample size of 70 students. Students in Class VII B, as the PBL group, were taught using Problem-Based Learning (PBL), while students in Class VII J, as the IBL group, were taught using the Inquiry-Based Learning (IBL) model. Thus, the two groups received different instructional treatments and were compared based on their mathematical creative thinking abilities before and after the instruction.

Instruments

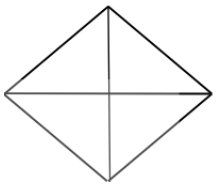
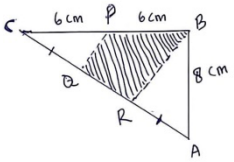
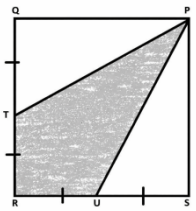
The instruments used in this study consisted of instructional materials and data collection instruments. The instructional materials included teaching modules and Student Worksheets (LKPD) designed in accordance with the syntax of the Problem-Based Learning and Inquiry-Based Learning models, which were then validated by university lecturers and subject teachers before being used in the study. The data collection instrument consisted of a test of mathematical creative thinking skills in the form of open-ended questions administered during the pretest and posttest. The test was designed based on four indicators of mathematical creative thinking skills: fluency, flexibility, originality, and elaboration. Each indicator is accompanied by a scoring rubric using a 0–4 scale to assess the quality of ideas, diversity, originality of answers, and students' ability to develop and elaborate on their solutions.

Before being used in the study, the test instrument underwent validity, reliability, difficulty level, and discriminant power tests. The validity test results showed that all test items

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v6i4.5519 Volume 6, Issue 4, October - December 2026, pp. 1792 –1806

were deemed valid, with validity coefficients of 0.79536, 0.75161, 0.74181, and 0.79111, respectively. The reliability test yielded a Cronbach's Alpha value of 0.767, which falls into the high category. The results of the difficulty level test showed that one question was classified as easy and three were classified as moderate, while the results of the discriminative power test showed that all questions were classified as adequate. In addition, the equivalence of the pretest and posttest was ensured through the consistency of indicators, question formats, difficulty levels, and scoring guidelines, so that the instrument could be used to measure changes in students' mathematical creative thinking abilities before and after the intervention (See, Table 2).

Table 2. Essay Questions for the Creative Thinking Skills Test

Indicator	Essay Questions
Fluency	A square has a side length of 8 cm. a. Identify at least two types of two-dimensional shapes that have the same area. b. Based on part a, draw each of these two-dimensional shapes. c. Determine the area of each of these two-dimensional shapes.
Flexibility	Mr. Budi has a tea plantation shaped like a diamond, as shown in the figure on the right. The lengths of the diagonals are 8 cm and 4 cm. Determine the area of this plane figure using at least two different methods. 
Originality	Look at the picture of the right triangle on the right. Line BR is parallel to line PQ, with point P as the midpoint of line BC. Calculate the area of the shaded region using a method different from the usual one. Explain why you used that method. 
Elaboration	The area of a park shaped as shown in the figure on the right is 100 cm^2. Determine the area of region TPUR. Write out the steps of your solution in detail and explain how you calculated the area of each required part to arrive at the area of region TPUR. 

Data Collection

Data collection for this study was conducted in three stages: the preparatory stage, the implementation stage, and the final stage. During the preparatory stage, the research instruments were developed and validated. The implementation stage involved administering a pretest, implementing the PBL model in experimental class 1 and the IBL model in experimental class 2 over four sessions, and concluding with a posttest. Subsequently, the data obtained were analyzed to address the research objectives.

Analysis

The data in this study were analyzed quantitatively using IBM SPSS Statistics software, version 25. The analysis began with descriptive statistics to determine the minimum, maximum, mean, and standard deviation of the pretest and posttest scores, as well as the N-Gain. Next, prerequisite tests were conducted, including a normality test using the Shapiro-Wilk test and a homogeneity test using Levene's test. Improvements in mathematical creative thinking skills were calculated using Normalized Gain (N-Gain) based on pretest and posttest scores, and then interpreted according to improvement categories. Next, the difference in improvements in mathematical creative thinking skills between the PBL and IBL groups was analyzed using an independent samples t-test on the N-Gain scores. Test results are reported in terms of the mean, t, degrees of freedom (df), p-value, confidence interval, and effect size.

Research Findings

The study was conducted with seventh-grade students at SMP Negeri 2 in Cilegon, specifically Class VII B as the PBL group and Class VII J as the IBL group. Before the instruction began, both groups took a pretest to assess the students' initial abilities in creative mathematical thinking. Next, each group received instruction over the course of four sessions on the topic of two-dimensional shapes, followed by a posttest. The pretest and posttest data were then used to calculate the N-Gain.

Learning in PBL groups is carried out through five steps: orienting students to the problem, organizing students for learning, facilitating individual and group investigations, developing and presenting their work, and analyzing and evaluating the problem-solving process. Students are presented with contextual problems through worksheets, then discuss them in groups to identify the problems and develop various strategies for solving them. The researcher acts as a facilitator throughout the inquiry process. Next, some groups present their solutions, and the other groups provide feedback. The lesson concludes with a discussion and reflection on the problem-solving process in Figure1.



Figure 1. PBL Classroom Learning Activities

Meanwhile, learning in the IBL group is conducted through the following stages: orientation, problem formulation, hypothesis formulation, data collection, hypothesis testing, and drawing conclusions. Students are presented with problems through worksheets and are then guided to formulate the problem and a tentative hypothesis. Next, students gather information through observation and discussion to test the hypotheses they have formulated.

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v6i4.5519 Volume 6, Issue 4, October - December 2026, pp. 1792 –1806

The researcher provides guidance throughout the investigation process and directs students to draw conclusions based on the results obtained.



Figure 2. IBL Class Learning Activities

Next, the results of the descriptive statistical analysis of the pretest, posttest, and N-Gain for classes that used the Problem-Based Learning and Inquiry-Based Learning models are presented in the Figure 2.

Data Description

Based on Table 3, the results of the descriptive statistical analysis show that there is a difference in the mean scores for students' mathematical creative thinking abilities between classes that used the Problem-Based Learning and Inquiry-Based Learning models at the pretest, posttest, and N-Gain stages. In the pretest phase, the average score for students in the PBL class was 23.54, while in the IBL class it was 24.11. This difference indicates that the students' initial mathematical creative thinking abilities in both classes were relatively similar. This is also supported by the standard deviations, which were not significantly different—6.308 in the PBL class and 4.503 in the IBL class—indicating that the distribution of students' initial abilities in both classes tended to be similar. After the intervention, the average posttest scores in both classes increased. The class that received instruction using the Problem-Based Learning model achieved an average posttest score of 82.77 with a standard deviation of 7.199, while the class that used the Inquiry-Based Learning model achieved an average score of 76.63 with a standard deviation of 5.605. The results show that both learning models were able to improve students' mathematical creative thinking skills; however, the improvement in learning outcomes was greater in the PBL class than in the IBL class.

When examined in terms of normalized gain (N-Gain), the PBL class achieved an average of 0.77, while the IBL class achieved an average of 0.69. Based on the N-Gain categories, both classes fall into the high category, but the PBL class's average N-Gain is higher than that of the IBL class. Thus, from a descriptive perspective, it can be concluded that both learning models are equally effective in improving students' mathematical creative thinking skills; however, the Problem-Based Learning model showed a greater improvement compared to the Inquiry-Based Learning model.

Table 3. Descriptive Statistics for Pretest, Posttest, and N-Gain in Mathematical Creative Thinking Ability

Experimental Class 1 (PBL)						
N	**Pretest**		**Posttest**		**N-Gain**	
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S
35	23,54	6,308	82,77	7,199	0,77	0,10

Experimental Class 1 (PBL)						
N	**Pretest**		**Posttest**		**N-Gain**	
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S
35	24,11	4,503	76,63	5,605	0,69	0,07

Prerequisite Test

Based on the results of the normality tests in Table 4, it is evident that all pretest, posttest, and N-Gain data have significance levels (Sig.) > 0.05. Therefore, it can be concluded that the pretest, posttest, and N-Gain data for both classes are normally distributed.

Table 4. Results of the Normality Test for Pretest and Posttest Data Creative Mathematical Thinking

Class	***Shapiro-Wilk***	
	Statistic	**Sig.**
Pretest Ex 1	0,959	0,217
Posttest Ex 2	0,971	0,476
Pretest Ex 1	0,958	0,199
Posttest Ex 2	0,974	0,554
N-Gain Ex 1	0,977	0,645
N-Gain Ex 2	0,970	0,446

Based on the results of the homogeneity test in the Table 4, all pretest, posttest, and N-Gain data have significance levels (Sig.) > 0.05. These results indicate that the variance of the data in both classes is homogeneous. In addition, the results of the normality test also indicate that the data are normally distributed. Since both of these assumptions are met, the research data are suitable for further analysis using the independent samples t-test.

Table 5. Results of the Homogeneity Test for Pretest and Posttest Data Mathematical Creative Thinking Ability

Data	**Lavene Statistik**	**Sig.**
Pretest	2,898	0,093
Posttest	1,780	0,187
N-Gain	2,246	0,139

Independent Samples t-Test

A hypothesis test was conducted using an independent samples t-test to determine whether there was a difference in the mathematical creative thinking abilities of students in the PBL and IBL classes after the intervention. The results of the t-test are shown in the following Table 6.

Table 6. Results of the Independent-Samples t-Test on Posttest Data Mathematical Creative Thinking Skills

Data	t-test for Equality of Means	Notes
Sig. (2-*tailed*)		
Posttest	0,001	H_0 is rejected and H_1 is accepted

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Based on the t-test for the posttest data, a Sig. (2-tailed) value of 0.000 was obtained. This value is less than 0.05 (0.001 < 0.05), so H_0 is rejected and H_1 is accepted. This indicates that there is a significant difference in mathematical creative thinking ability between students who learned using the PBL and IBL models after receiving the treatment. Based on the research findings, it can be concluded that both the Problem-Based Learning (PBL) and Inquiry-Based Learning (IBL) models are effective in enhancing students' creative mathematical thinking skills. However, the results of the analysis show that there is a significant difference between the two models, with students who learn using the PBL model demonstrating better mathematical creative thinking skills than those who learn using the IBL model.

Discussion

The results of the study show that the implementation of both the Problem-Based Learning (PBL) and Inquiry-Based Learning (IBL) models is equally effective in developing students' creative mathematical thinking skills. The average pretest score in the PBL class was 23.54 and in the IBL class was 24.11, while the average posttest scores were 82.77 and 76.63, respectively. The improvement in mathematical creative thinking skills, as measured by N-Gain, averaged 0.77 in the PBL class and 0.69 in the IBL class. The results of the independent samples t-test on N-Gain indicate a significant difference between the two groups ($p < 0.001$). These results show that, although both models yielded improvements in descriptive terms, the improvement in the PBL class was greater than that in the IBL class.

A key feature of both student-centered models is that they provide students with opportunities to actively construct knowledge through problem-solving, discussion, and conceptual exploration. This is consistent with Kadir et al., (2022) who state that creative thinking skills develop through students' active engagement in the learning process. This finding is consistent with constructivism, which posits that knowledge becomes more meaningful when students are actively engaged in the learning process. These findings are also supported by Dodopo et al., (2022) who state that students' active engagement in learning can help them develop a more meaningful conceptual understanding In addition, the findings of this study also support the research by Ari Septian (2020) which states that PBL can enhance students' creative mathematical thinking skills through problem-solving activities, as well as the research by Pujiastuti et al., (2021) which explains that IBL encourages students to discover concepts independently, thereby fostering the development of their creativity. Similar results were also reported by Selfiani et al., (2022) who found that problem-solving activities can enhance students' creative mathematical thinking skills.

Although both models yielded positive results, the PBL model demonstrated better mathematical creative thinking skills than the IBL model. This is likely because PBL uses contextual problems as the starting point for learning, thereby encouraging students to identify problems, propose various alternative solutions, engage in discussion, and evaluate the results of their solutions. These activities provide students with greater opportunities to develop fluency, flexibility, and elaboration in their thinking. According to Dalilan & Sofyan (2022), creative mathematical thinking is demonstrated through the ability to generate a variety of ideas and problem-solving strategies. These findings indicate that PBL provides students with greater scope to explore various problem-solving strategies (Purwoko, 2023). The results of this study support the findings of Amelia & Pujiastuti (2020) who state that problem-based learning is effective in enhancing creative thinking skills because it provides students with the opportunity to develop a variety of problem-solving strategies. This finding is also supported by Marnala

(2023) who states that PBL has a positive effect on students' mathematical creative thinking skills.

Differences in achievement between the two models were also evident across each indicator of mathematical creative thinking skills. In the PBL class, the average scores for the indicators were 3.46 for fluency, 3.17 for flexibility, 3.29 for originality, and 3.34 for elaboration. Meanwhile, in the IBL class, the scores for each indicator were 3.37 for fluency, 2.77 for flexibility, 3.51 for originality, and 2.83 for elaboration. The data show that PBL achieved higher scores on the indicators of fluency, originality, and elaboration, while IBL achieved higher scores on the indicator of originality. Thus, the research findings do not indicate that PBL outperforms IBL on all indicators, but rather that there are differences in the characteristics of achievement between the two models. Higher levels of fluency in PBL may be related to problem-solving activities that encourage students to generate multiple solutions, while higher levels of originality in IBL classes may be related to students' opportunities to explore and discover solutions independently.

The flexibility indicator had the lowest score in both groups, at 3.17 for PBL and 2.77 for IBL. These findings indicate that students still tend to use a single problem-solving strategy and are not yet accustomed to exploring various alternative solutions. This situation indicates the need for instruction that provides students with opportunities to use a variety of problem-solving strategies when solving a math problem. These findings are consistent with those of Susilawati et al., (2025) who state that flexibility can be developed through regular practice with open-ended problems that encourage students to use more than one problem-solving strategy. These findings are supported by Suretdawati (2022) who states that familiarizing students with various problem-solving alternatives can enhance their ability to think creatively in mathematics.

The effectiveness of instruction in both groups was rated as "very good," with an average score of 3.90 in the PBL class and 3.88 in the IBL class. Student responses to the instruction also showed positive results, with 81.48% in the PBL class and 80.97% in the IBL class. The results indicate that both models can be applied according to learning characteristics and elicit positive responses from students. In PBL, student engagement in identifying problems, discussing them, and developing alternative solutions fosters creative thinking. Meanwhile, in the IBL, the process of formulating problems, gathering information, testing hypotheses, and drawing conclusions provides students with the opportunity to build understanding through discovery. This demonstrates that effective teaching practices help enhance students' creative thinking skills (Fitriani & Pujiastuti, 2026).

The results of this study are consistent with previous research showing that both PBL and IBL can be used to develop mathematical creative thinking skills. However, this study provides a more specific picture because it directly compares the two models in the context of plane geometry by examining posttest scores, improvement measured by N-Gain, and achievement on each indicator of mathematical creative thinking skills. Differences in research context-such as student characteristics, instructional content, and teaching practices-must be taken into account when comparing the results of this study with those of previous studies.

The novelty of this study lies in its direct comparison of the effects of the PBL and IBL models on students' mathematical creative thinking skills in the area of plane figures by analyzing not only their final performance and improvement as measured by N-Gain, but also their achievement on each indicator of creative thinking skills. The results of the study show that PBL yields higher scores in fluency, originality, and elaboration, while IBL yields higher scores in originality. These findings provide insight into the characteristics of creative thinking

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v6i4.5519 Volume 6, Issue 4, October - December 2026, pp. 1792 –1806

skills in both models, while also demonstrating that each model exhibits different patterns of indicator achievement.

This study has several limitations. First, the study was conducted in two classes at a single school; therefore, the results should be considered in the context of the characteristics of the school and the students involved. Second, the model was implemented over four sessions and only on the topic of plane figures; thus, it does not yet illustrate the application of PBL and IBL to other mathematics topics or over a longer period of instructionThird, although the pretest results showed no significant difference between the two groups, differences in students' individual abilities may still have influenced the study's results. Fourth, the instrument had limitations in distinguishing between the indicators of flexibility and originality, particularly regarding the requirement to generate alternative solutions. These limitations may serve as considerations for future research to include a more diverse sample and a wider range of schools, extend the duration of implementation, use different materials, and develop instruments that more clearly distinguish between each indicator of mathematical creative thinking ability.

Conclusion

This study found that both problem-based learning (PBL) and inquiry-based learning (IBL) were accompanied by improvements in students' mathematical creative thinking skills in the context of learning plane figures. However, students in the PBL group achieved a higher mean posttest score than those in the IBL group (82.77 versus 76.63) and demonstrated a greater mean normalized gain (0.77 versus 0.69). An independent-samples t-test on normalized gain scores confirmed a statistically significant difference in improvement between the two groups, $t(68) = 3.761$, $p < .001$. Taken together, these findings indicate that, within the sample and instructional conditions examined, PBL was associated with greater improvement in mathematical creative thinking than IBL. At the indicator level, students in the PBL group achieved higher scores in fluency and elaboration, whereas flexibility showed the lowest achievement in both groups. This pattern highlights the importance of considering not only overall improvement but also the development of individual dimensions of mathematical creative thinking. In particular, the relatively low achievement in flexibility points to a need for instructional activities that explicitly encourage students to generate, compare, and evaluate different problem-solving strategies. PBL may therefore be considered a promising instructional option for fostering mathematical creative thinking, while the findings also identify flexibility as an area requiring further attention in both approaches. These conclusions should be interpreted within the scope of the study, which involved 70 students from two classes at a single school and four instructional sessions on plane figures. Future research should examine whether similar patterns emerge across more diverse student populations, mathematical topics, and instructional contexts, as well as over longer instructional periods. Further investigation should also explore how activities specifically designed to promote the use of multiple solution strategies can strengthen flexibility within both PBL and IBL.

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Declarations

Conflict of Interest : The authors declare that there are no conflicts of interest.

Auhor Contributions : K.F.: Conceptualization, Methodology, Investigation, Resources, Data curation, Formal analysis, Writing – original draft, Writing – review & editing.
H.P.: Supervision, Methodology, Writing – review & editing.
M.F.: Supervision, Investigation, Writing – review & editing.

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Kognitif: Jurnal Riset HOTS Pendidikan Matematika
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