

The Development of Problem-Solving and Creative Thinking Skills Using Problem-Based Learning (PBL) in Geometry for Sixth-Grade Students

Tingfeng Yi^{*1} Siribhong Bhasiri²
2077503814@qq.com*

Received: May 4, 2026 Revised: June 1, 2026 Accepted: June 4, 2026

Abstract

The objectives of this research were 1) to examine the effects of the Problem-Based Learning (PBL) approach on students' problem-solving skills; and 2) to investigate the effects of the Problem-Based Learning (PBL) approach on students' creative thinking skills. A quasi-experimental pre-test and post-test between experimental and control group design were employed, involving 91 sixth-grade students. The experimental group received PBL instruction, while the control group was taught using conventional methods during the first semester of the 2025 academic year in a geometry unit. Data were analyzed using statistics including the arithmetic mean (M), standard deviation (S.D.), and t-test for independent samples.

The research findings revealed that:

1. In terms of problem-solving skills, the experimental group achieved a significantly higher post-test total score (M=112.46, S.D.=8.68) than the control group (M=91.35, S.D.=10.23), the average mean showing a statistically significant at the .05 level ($t=6.892$, $p<0.001$), which considered focus on the experimental and the control groups get the improvement score of all dimensions increased by 29.88 points and 8.93 points respectively while compare between pre-test and post-test.

2. In terms of creative thinking skills, the experimental group obtained a significantly higher post-test total score (M=12.35, S.D.=1.57) than the control group (M=8.77, S.D.=1.89), the average mean showing a statistically significant at the .05 level ($t=6.789$, $p<0.001$), which considered focus on the experimental and the control groups get the improvement score of all dimensions increased by 4.78 points and 1.12 points respectively while compare between pre-test and post-test.

Keywords: Problem-Based Learning (PBL), Geometry, Problem-Solving Skills, Creative Thinking Skills

*Corresponding Author

¹⁻²Faculty of Education, Khon Kaen University

การพัฒนาทักษะการแก้ปัญหาและการคิดเชิงสร้างสรรค์ โดยใช้การจัดการเรียนรู้แบบใช้ปัญหาเป็นฐาน (PBL) ในหน่วยการเรียนรู้เรื่องเรขาคณิต สำหรับนักเรียนชั้นประถมศึกษาปีที่ 6

ถึงเพ็ง ยี่¹ ศิริพงษ์ เพียศิริ²
2077503814@qq.com*

ส่งบทความ 4 พฤษภาคม 2569 แก้ไข 1 มิถุนายน 2569 ตอรับ 4 มิถุนายน 2569

บทคัดย่อ

การวิจัยนี้มีวัตถุประสงค์ 1) เพื่อวิเคราะห์ผลของการจัดการเรียนรู้โดยใช้ปัญหาเป็นฐาน (Problem-Based Learning: PBL) ต่อทักษะการแก้ปัญหาของนักเรียน และ 2) เพื่อวิเคราะห์ผลของการจัดการเรียนรู้แบบ PBL ต่อทักษะการคิดเชิงสร้างสรรค์ของนักเรียน การวิจัยใช้รูปแบบกึ่งทดลองแบบวัดก่อน-หลัง โดยมีกลุ่มควบคุมและกลุ่มทดลอง กลุ่มตัวอย่างเป็นนักเรียนชั้นประถมศึกษาปีที่ 6 จำนวน 91 คน ซึ่งกลุ่มทดลองได้รับการจัดการเรียนรู้ด้วยรูปแบบ PBL ส่วนกลุ่มควบคุมได้รับการสอนแบบปกติ การทดลองดำเนินการในหน่วยการเรียนรู้เรื่องเรขาคณิตในภาคเรียนที่ 1 ปีการศึกษา 2568 การวิเคราะห์ข้อมูลใช้สถิติเชิงพรรณนา ได้แก่ ค่าเฉลี่ย (M) ส่วนเบี่ยงเบนมาตรฐาน (S.D.) และการทดสอบ t-test แบบอิสระ

ผลการวิจัยพบว่า

1. ด้านทักษะการแก้ปัญหา กลุ่มทดลองมีคะแนนเฉลี่ยหลังการทดลอง ($M=112.46$, $S.D.=8.68$) สูงกว่ากลุ่มควบคุม ($M=91.35$, $S.D.=10.23$) อย่างมีนัยสำคัญที่ระดับ .05 ($t = 6.892$, $p < 0.001$) โดยคะแนนพัฒนาการรวมในทุกด้านของกลุ่มทดลองเพิ่มขึ้น 29.88 คะแนน ขณะที่กลุ่มควบคุมเพิ่มขึ้น 8.93 คะแนน เมื่อเปรียบเทียบระหว่างคะแนนก่อนเรียนและหลังเรียน
2. ด้านทักษะการคิดเชิงสร้างสรรค์ กลุ่มทดลองมีคะแนนเฉลี่ยหลังการทดลอง ($M=12.35$, $S.D.=1.57$) สูงกว่ากลุ่มควบคุม ($M=8.77$, $S.D.=1.89$) อย่างมีนัยสำคัญที่ระดับ .05 ($t=6.789$, $p < 0.001$) โดยคะแนนพัฒนาการรวมในทุกด้านของกลุ่มทดลองเพิ่มขึ้น 4.78 คะแนน ขณะที่กลุ่มควบคุมเพิ่มขึ้น 1.12 คะแนน เมื่อเปรียบเทียบระหว่างคะแนนก่อนเรียนและหลังเรียน

คำสำคัญ: การจัดการเรียนรู้โดยใช้ปัญหาเป็นฐาน (PBL), เรขาคณิต, ความสามารถในการแก้ปัญหา, ความสามารถในการคิดเชิงสร้างสรรค์

* ผู้ประพันธ์บรรณกิจ

¹⁻² คณะศึกษาศาสตร์ มหาวิทยาลัยขอนแก่น

Introduction

With the continuous development of society, particularly in the context of the information age, the demand for innovative talents has been steadily increasing. Modern society requires students not only to acquire solid disciplinary knowledge but also to develop creative thinking and real-world problem-solving skills. In this context, mathematics education, especially geometry instruction, plays an important role in cultivating students' thinking abilities and creativity (Ministry of Education, 2022). However, mathematics instruction in primary schools still largely relies on traditional teacher-centered approaches, in which teaching activities are mainly dominated by direct instruction and students tend to passively receive knowledge, with limited opportunities for active inquiry and deep thinking. To some extent, conventional instructional approaches may restrict the development of students' problem-solving skills and creative thinking skills (Jiang & Zhang, 2025). Particularly in geometry learning, because the content involves spatial imagination, figure interpretation, and logical reasoning, many primary school students experience difficulties in constructing systematic conceptual understanding. This issue becomes particularly evident at the sixth-grade level, when students begin transitioning from concrete thinking to more abstract mathematical reasoning.

In the researcher's classroom observations, many students tended to rely heavily on teacher demonstrations and formula memorization when learning topics such as the circumference and area of circles. However, when geometry problems were presented in authentic contexts requiring interpretation, reasoning, and multi-step analysis, students often experienced difficulties in identifying geometric relationships and flexibly applying prior knowledge to solve problems. For example, when geometry learning activities involved real-life situations such as calculating the area of flower gardens, estimating pizza sizes, or designing running tracks, many students demonstrated limited ability to analyze geometric relationships and often relied on routine formula application. In addition, classroom discussions were often limited to answer sharing rather than collaborative inquiry and reflective thinking. These observations suggest that traditional instructional approaches still have certain limitations in promoting students' problem-solving skills and creative thinking skills.

With the continuous advancement of educational reform, increasing attention has been given to student-centered instructional approaches. Problem-Based Learning (PBL), as a problem-oriented instructional approach, was first systematically developed in medical education and was later gradually applied in other fields (Barrows & Mitchell, 1975). This approach emphasizes learning through authentic problem situations, enabling students to actively construct knowledge through problem analysis, collaborative inquiry, and reflection. Previous studies have shown that PBL can effectively promote active learning, collaborative learning, and higher-order thinking skills (Hmelo-Silver, 2004; Savery, 2015). Juandi and Tamur (2021), in a meta-analysis of PBL studies, reported that PBL has a positive effect on students' mathematical thinking abilities. Anazifa and Djukri (2017) also noted that Problem-Based Learning can effectively enhance students' thinking skills. PBL has gradually been applied in various educational contexts and has demonstrated positive instructional outcomes (Hung, 2015).

In mathematics education, researchers generally agree that problem situations and inquiry-based activities can effectively promote students' understanding and transfer of knowledge, while also

improving their problem-solving skills (Li, 2023). Geometry learning itself is characterized by openness and multiple possible solution pathways, requiring students to apply spatial imagination and logical reasoning during problem analysis. These characteristics provide favorable conditions for the development of creative thinking skills. Therefore, integrating PBL into geometry instruction has been considered a potentially valuable instructional approach. Siregar et al. (2020) reported that PBL has a positive effect on students' mathematical creative thinking ability, while Fitriani et al. (2021) found that the Problem-Based Learning approach can improve elementary school students' mathematical problem-solving ability. This is because geometry learning often requires students to observe figures, analyze spatial relationships, propose solution strategies, and verify their reasoning processes, which are highly consistent with the inquiry and collaborative learning processes emphasized in PBL. These studies suggest that PBL may effectively support the development of students' higher-order thinking abilities in mathematics learning.

Although previous studies have produced valuable findings regarding PBL implementation, geometry instruction, and student ability development, several limitations remain. First, most PBL studies have focused on higher education or general subject contexts, while systematic empirical research in primary mathematics education, particularly in geometry instruction, remains relatively limited. Second, existing studies in geometry education have mainly focused on teaching content and instructional methods, with relatively limited attention given to the systematic cultivation of students' problem-solving skills and creative thinking skills (Lai & Hwang, 2016). In addition, although previous research has explored the relationship between PBL and students' thinking abilities, most studies have focused on a single dimension of ability, while integrated investigations of both problem-solving skills and creative thinking skills within primary geometry learning contexts remain insufficient. At the same time, although both problem-solving skills and creative thinking skills are regarded as essential competencies in mathematics learning (NCTM, 2000; Ministry of Education, 2022), relatively few studies have examined their coordinated development within specific instructional contexts.

Based on the above background and research gaps, further empirical investigation of instructional approaches in specific teaching contexts is necessary. Therefore, this study was conducted in the context of sixth-grade geometry instruction and implemented the Problem-Based Learning (PBL) approach to examine its effects on students' problem-solving and creative thinking skills through a classroom-based experiment. The study focuses on whether the Problem-Based Learning (PBL) approach can effectively promote the development of these skills in geometry learning and examines its effectiveness in primary mathematics classrooms. By comparing the learning outcomes of the experimental and control groups, this study aims to provide practical implications for primary mathematics teaching and empirical support for fostering students' higher-order thinking skills.

Research Objectives

1. To examine the effects of the Problem-Based Learning (PBL) approach on students' problem-solving skills.
2. To investigate the effects of the Problem-Based Learning (PBL) approach on students' creative thinking skills.

Research Scope

1. Population and Sample

The population of this study consisted of all sixth-grade students at H Primary School in City C, China, during the first semester of the 2025 academic year. The grade comprised five classes with a total of 244 students.

The sample included 91 students from two intact sixth-grade classes at the same school, with 46 students in the experimental group and 45 in the control group. The participants were selected using cluster random sampling. Before the instructional intervention, pre-tests on problem-solving skills and creative thinking skills were conducted for both groups. Independent samples t-tests indicated no significant differences between the experimental and control groups ($p > 0.05$), confirming the homogeneity and comparability of the sample. The instructional content in this study was selected from Unit 5 “Circle” in the Grade 6 mathematics textbook published by the People’s Education Press (PEP). The geometry topics included: (1) Introduction to the Circle, (2) Circumference of a Circle, (3) Area of a Circle, and (4) Sector. A total of four lesson plans were designed based on the Problem-Based Learning (PBL) approach and implemented during the experimental instruction. The instructional intervention was conducted over four sessions, with each lesson lasting approximately 40 minutes.

2. Research Variables

The independent variable in this study was the instructional approach, specifically the Problem-Based Learning (PBL) approach. The instructional process included problem situation introduction, group discussion and analysis, collaborative problem-solving activities, presentation, and reflection.

The dependent variables included problem-solving skills and creative thinking skills. Problem-solving skills were assessed across four dimensions: problem understanding, plan formulation, plan implementation, and reflection, based on the problem-solving framework proposed by OECD (2013), which emphasizes the ability to analyze, process, and solve problems in contextualized situations. Creative thinking skills were measured in terms of three dimensions: fluency, flexibility, and originality, based on Guilford’s theory of divergent thinking (Guilford, 1967).

To ensure internal validity, this study-controlled variables such as teaching content, instructional progress, teacher, and instructional time to minimize the influence of external factors on the results. Specifically, both groups were taught by the same teacher and received the same instructional time and teaching content to ensure the comparability of the results.

3. Definition of Terms

1) Problem-Based Learning (PBL) is a problem-oriented and student-centered instructional approach proposed by Barrows (1986). It emphasizes learning through real-world problem contexts, enabling students to actively construct knowledge through inquiry. In this study, the PBL approach was applied to sixth-grade geometry instruction and implemented through five stages: problem scenario design, problem analysis, plan formulation, plan implementation, and reflection.

2) Problem-Solving Skills refer to the skills required to apply existing knowledge and strategies to resolve complex or situational problems (OECD, 2013). In this study, these skills were

examined within the context of primary school geometry learning and assessed across four dimensions: problem understanding, plan formulation, plan implementation, and reflection.

3) Creative Thinking Skills refer to skills involved in generating novel and valuable ideas in problem situations, as defined by Joy Paul Guilford (1967). In this study, these skills were assessed through geometry-based tasks and measured across three dimensions: fluency, flexibility, and originality.

Research Methodology

1. Research Design

This study adopted a quasi-experimental pre-test–post-test control group design to examine the effects of the Problem-Based Learning (PBL) approach on students’ problem-solving and creative thinking skills by comparing changes between the experimental and control groups before and after the instructional intervention.

2. Research Instruments

This study employed two types of research instruments: lesson plans and skills tests.

1) Lesson Plans

The lesson plans used in this study were developed based on the learning objectives, curriculum indicators, and geometry content in Unit 5 “Circle” of the Grade 6 mathematics textbook published by the People’s Education Press (PEP). The instructional procedures followed the Problem-Based Learning (PBL) approach, including problem situation introduction, group discussion and analysis, problem-solving activities, presentation, and reflection. The lesson plans were reviewed by experts, and content validity was assessed using the Index of Item-Objective Congruence (IOC).

As shown in Figure 1, students actively participated in collaborative discussion and classroom interaction during the implementation of the PBL activities.



Figure 1. Collaborative inquiry activities in the PBL geometry classroom

2) Skills Tests

2.1) Problem-Solving Skills Test

This test consisted of pre-test and post-test components and was used to assess students' understanding of basic geometric concepts as well as their skills to apply knowledge in contextualized problem situations. The test items were designed according to the geometry learning objectives and the problem-solving framework proposed by OECD (2013).

2.2) Creative Thinking Skills Test

This test also included pre-test and post-test components and was adapted from the Chinese version of the Test for Creative Thinking (TCI-C) developed by Li (2012). The original TCI was developed by Janusz Kujawski and has been widely applied in creativity research (Karwowski, 2008). Students were required to complete figure-based composition tasks within a limited time and assign titles to their work. The assessment focused on three dimensions of creative thinking: fluency, flexibility, and originality, based on Guilford's theory of divergent thinking (Guilford, 1967).

3. Instrument Validity and Reliability

1) Validity. Content validity was established through expert review by three specialists who evaluated the test content and scoring criteria. The Index of Item-Objective Congruence (IOC) was used to assess the alignment between test items and research objectives. IOC values ranged from 0.67 to 1.00, exceeding the acceptable threshold of 0.50, with most items achieving 1.00. Minor revisions were made based on expert feedback to finalize the instruments.

2) Item Analysis. For the problem-solving skills test, item quality was examined using difficulty and discrimination indices. The difficulty index (p) ranged from 0.32 to 0.78, indicating an appropriate level of difficulty for sixth-grade students. The discrimination index (r) ranged from 0.31 to 0.72, demonstrating satisfactory item discrimination. For the creative thinking skills test, the difficulty index ranged from 0.35 to 0.76, while the discrimination index ranged from 0.30 to 0.69. These results indicate that the test items were of appropriate difficulty and demonstrated acceptable discriminatory power.

3) Reliability. Internal consistency was assessed using Cronbach's alpha. The results indicated good reliability, with coefficients of $\alpha=0.87$ for the problem-solving skills test and $\alpha=0.85$ for the creative thinking skills test, indicating high stability and consistency.

4. Data Collection

Data were collected through a combination of pre-test and post-test procedures, as follows:

1) Prior to the instructional intervention, both the experimental and control groups completed the pre-test to assess their problem-solving skills and creative thinking skills. 2) After the intervention, both groups completed the post-test to measure changes in their abilities.

5. Data Analysis

Data were analyzed using SPSS software. Descriptive statistics (mean and standard deviation) were used to summarize students' performance. Independent samples t-tests were conducted to compare differences between the experimental and control groups in both the pre-test and post-test results. Paired samples t-tests were used to examine changes within the same group before and after the instructional intervention.

Results

This study analyzed the experimental data in line with the established research objectives to examine the effectiveness of the PBL approach in primary school geometry classrooms. The results are presented in two aspects: 1) the effects of the Problem-Based Learning (PBL) approach on students' problem-solving skills, and 2) the effects of the Problem-Based Learning (PBL) approach on students' creative thinking skills.

1. The effects of PBL on Students' Problem-Solving Skills

The results indicate that the Problem-Based Learning (PBL) approach significantly enhances sixth-grade students' geometric problem-solving skills. It is more effective than conventional teaching methods and shows positive effects across all dimensions, including problem understanding, plan formulation, plan implementation, and reflection. To examine the effects of the Problem-Based Learning (PBL) approach on students' problem-solving skills, this study conducted a comparative analysis of pre-test and post-test results between the experimental and control groups, as shown in Table 1.

Table 1. The effects of the Problem-Based Learning (PBL) approach on students' problem-solving skills

Indicator	Experimental (Pre-test M±SD)	Experimental (Post-test M±SD)	Control (Pre-test M±SD)	Control (Post-test M±SD)	t (post-test, between groups)	p
Total score	82.58±9.88	112.46±8.68	82.42±10.12	91.35±10.23	6.892	< .001
Problem Understanding	20.09±3.46	28.12±3.12	20.68±3.57	21.88±3.77	5.234	< .001
Plan Formulation	20.12±3.21	26.46±3.35	20.03±3.35	23.12±3.99	4.789	< .001
Plan Implementation	21.35±3.68	30.23±2.88	21.10±3.54	24.65±3.54	6.123	< .001
Reflection	18.31±3.12	20.64±3.01	17.62±3.23	19.69±3.21	4.321	< .001

Note: * Statistically significant at .05.

Before the instructional intervention, no significant differences were found between the experimental and control groups in the total scores or any dimensions of problem-solving skills ($p > .05$), indicating good baseline equivalence. After the intervention, the experimental group significantly outperformed the control group. Specifically, the post-test total score of the experimental group ($M=112.46$, $S.D.=8.68$) was substantially higher than that of the control group ($M=91.35$, $S.D.=10.23$), with a highly significant difference ($t=6.892$, $p<.001$). Significant differences were also observed across all dimensions, including understanding the problem ($t=5.234$, $p<.001$), plan formulation ($t=4.789$, $p<.001$), plan implementation ($t=6.123$, $p<.001$), and reflection ($t=4.321$, $p<.001$), suggesting that PBL may effectively support multiple stages of problem-solving.

Further paired-sample t-test comparisons within the experimental group revealed a significant improvement in problem-solving skills after the intervention. The total score increased by 29.88 points, with statistically significant differences ($p < .001$), indicating that the PBL approach effectively enhances students' overall problem-solving skills. Among the dimensions, the most notable improvements were observed in solution implementation and problem understanding, suggesting that PBL helps students transform knowledge into practical solution strategies and improves their skills to analyze and comprehend problems. In contrast, the control group showed only slight improvements under conventional teaching methods, indicating the limited effectiveness of conventional teaching methods in promoting higher-order problem-solving skills. Overall, the findings demonstrate that the PBL

approach significantly enhances sixth-grade students' geometric problem-solving skills and shows clear advantages over conventional teaching methods.

2. The effects of PBL on Students' Creative Thinking Skills

The results also show that the PBL approach significantly improves sixth-grade students' creative thinking skills, with notable effects across the three dimensions of fluency, flexibility, and originality. Among these, improvements in fluency and originality were more pronounced, while the improvement in flexibility was relatively moderate. To examine the impact of PBL, comparisons were conducted between the experimental and control groups before and after the instructional intervention, as shown in Table 2.

Table 2. The effects of the Problem-Based Learning (PBL) approach on students' creative thinking skills

Indicator	Experimental (Pre-test M±SD)	Experimental (Post-test M±SD)	Control (Pre-test M±SD)	Control (Post-test M±SD)	t (post-test, between groups)	p
Total score	7.57±1.89	12.35±1.57	7.65±1.99	8.77±1.89	6.789	< .001
Fluency	3.21±1.02	5.12±0.99	3.29±1.06	3.46±1.02	5.123	< .001
Flexibility	2.12±0.57	2.79±0.46	2.16±0.60	1.99±0.51	4.567	< .001
Originality	2.23±0.79	4.43±0.79	2.21±0.81	3.32±0.85	3.890	< .001

Note: * Statistically significant at .05

Before the intervention, no significant differences were found between the two groups in overall creative thinking skills or any of its dimensions ($p>.05$), indicating comparable baseline levels. After the intervention, the experimental group significantly outperformed the control group. Specifically, the post-test total score of the experimental group ($M=12.35$, $S.D.=1.57$) was significantly higher than that of the control group ($M=8.77$, $S.D.=1.89$), with a highly significant difference ($t=6.789$, $p<.001$). Significant differences were also observed in fluency ($t=5.123$, $p<.001$), flexibility ($t=4.567$, $p<.001$), and originality ($t=3.890$, $p<.001$), indicating that PBL positively promotes multiple aspects of creative thinking.

Further paired-sample t-test comparisons within the experimental group showed that the experimental group achieved significant improvements in creative thinking skills after the intervention. The total score increased by 4.78 points, with statistically significant differences ($p<.001$), demonstrating the effectiveness of the PBL approach in enhancing overall creative thinking. Among the dimensions, fluency and originality showed the most substantial gains, suggesting that PBL, through open-ended problem contexts and collaborative inquiry activities, effectively stimulates students' divergent thinking and creative expression. Although flexibility also improved, the magnitude was relatively smaller, indicating that the development of this skill may require longer-term instructional support. In contrast, the control group exhibited only minor improvements under conventional teaching methods, suggesting the limited effectiveness of conventional teaching methods in fostering creative thinking.

In summary, the PBL approach significantly enhances sixth-grade students' creative thinking skills and is more effective than conventional teaching methods. Notably, its impact is stronger on fluency and originality, while improvements in flexibility are relatively moderate.

Discussion

This study examined the effects of the Problem-Based Learning (PBL) approach on students' problem-solving and creative thinking skills. The findings indicate that the implementation of PBL in sixth-grade geometry instruction significantly improves both skills and is more effective than conventional teaching methods.

From a pedagogical perspective, PBL organizes learning around problems and emphasizes students' active engagement in inquiry and discussion within problem situations. Through the processes of understanding, analyzing, and solving problems, students gradually construct knowledge. This learning approach is consistent with constructivist learning theory and the concept of "learning by doing" (Dewey, 1938), as well as with the view that knowledge construction is promoted through learners' participation in practical activities and the accumulation of experience (Liu, 2022). In the present study, the experimental group was taught using a PBL-based instructional process that included problem situation introduction, group discussion and problem analysis, solution design, solution implementation, and presentation and reflection activities. During the classroom activities, students worked collaboratively to analyze geometric problems, discuss different solution strategies, and explain their reasoning to peers. When students encountered difficulties in understanding geometric concepts or solving problems, the teacher guided them through questioning and classroom discussion to support problem analysis and knowledge construction.

In terms of problem-solving skills, students in the experimental group demonstrated significant improvement across all dimensions, including problem understanding, plan formulation, solution implementation, and reflection. This suggests that problem-driven learning environments effectively support the development of students' cognitive abilities throughout the problem-solving process. These findings are consistent with those of Guo et al. (2023), who found that instructional approaches structured around "understanding—representation—planning—execution—monitoring and reflection" effectively enhance students' problem-solving skills. The findings of this study further showed that students in the experimental group demonstrated more notable improvement in the dimensions of problem understanding and plan implementation. In the PBL classroom, students were required not only to understand the conditions of geometric problems, but also to continuously analyze, revise, and improve their solution strategies through group discussion and reflection activities. This ongoing process of analysis and reflection may help strengthen students' geometric problem-solving skills.

Regarding creative thinking skills, the experimental group showed improvement across fluency, flexibility, and originality, with more pronounced gains in fluency and originality. This finding aligns with the structural framework of creative thinking (Guilford, 1967). Previous studies have also highlighted the importance of task design in fostering students' creative thinking (Jiang & Zhang, 2025). In the PBL learning environment, students are required to generate multiple solutions to the same problem and refine their ideas through interaction, thereby facilitating the development of divergent thinking. In the creative thinking assessment used in this study, students were required to complete figure-combination tasks and assign titles to their work. This process emphasized the reorganization and creative expression of given visual information. In addition, students in the PBL classroom were encouraged to propose multiple approaches to solving the same geometric problem and compare

the feasibility of different solutions through peer discussion and group interaction. These classroom activities provided students with opportunities to express different viewpoints and explore alternative ways of thinking, thereby supporting the development of fluency and originality.

Compared with the experimental group, students in the control group who received conventional instruction demonstrated only limited improvement, and most dimensions did not reach statistical significance. This finding suggests that teacher-centered instruction may have certain limitations in promoting students' problem-solving and creative thinking skills. Traditional classroom instruction tends to emphasize knowledge transmission and standardized solution procedures, while providing relatively limited opportunities for discussion, independent analysis, and collaborative inquiry.

Taken together, the findings of this study suggest that integrating the PBL approach into primary school geometry instruction not only increases students' engagement in problem-driven learning, but also promotes problem analysis, collaborative inquiry, reflection, and deeper cognitive engagement through activities such as problem situations, group discussion, and presentation and reflection tasks. These processes contribute to the development of students' problem-solving and creative thinking skills and provide important pedagogical implications for primary mathematics education.

Suggestion

1. Practical Implications

1.1 Strengthening problem-based instructional design. Geometry instruction should be organized around problem situations, enabling students to construct knowledge through problem-solving processes and thereby enhance their problem-solving skills.

1.2 Emphasizing collaborative learning and reflective processes. Classroom activities should incorporate group collaboration and structured reflection to support students in refining their thinking through discussion and feedback.

1.3 Improving multidimensional assessment approaches. Evaluation should balance both learning outcomes and learning processes, with particular attention to students' cognitive performance and creative thinking in problem-solving activities.

2. Recommendations for Future Research

2.1 Expanding research across diverse educational contexts. Future studies should be conducted in different regions and school types to further examine the applicability of the PBL approach.

2.2 Conducting long-term intervention studies. Extending the duration of instructional interventions (e.g., over a semester or an academic year) may provide deeper insights into the sustained effects of PBL on students' development, particularly regarding the long-term development of students' problem-solving and creative thinking skills.

2.3 Further exploring dimensions of creative thinking. Future research should examine differences among fluency, flexibility, and originality, and explore how instructional design can better support their development.

Acknowledgements

The author thanks all participants and staff who contributed to this study.

References

- Anazifa, R. D., & Djukri. (2017). Project-based learning and problem-based learning: Are they effective to improve student's thinking skills? *Jurnal Pendidikan IPA Indonesia*, 6(2), 346–355. <https://doi.org/10.15294/jpii.v6i2.11100>
- Barrows, H. S. (1986). A taxonomy of problem-based learning methods. *Medical Education*, 20(6), 481–486. <https://doi.org/10.1111/j.1365-2923.1986.tb01386.x>
- Barrows, H. S., & Mitchell, D. L. (1975). An innovative course in undergraduate neuroscience: Experiment in problem-based learning with “problem boxes”. *British Journal of Medical Education*, 9(4), 223–230. <https://doi.org/10.1111/j.1365-2923.1975.tb01930.x>
- Dewey, J. (1938). *Experience and education*. Macmillan.
- Fitriani, N., Turmudi, & Prabawanto, S. (2021). Problem-based learning approach to improve students' mathematical problem-solving ability in elementary school. *Journal of Physics: Conference Series*, 1806(1), 012071. <https://doi.org/10.1088/1742-6596/1806/1/012071>
- Guilford, J. P. (1967). *The nature of human intelligence*. McGraw-Hill.
- Guo, L., Li, M., & He, G. (2023). Teaching strategies for improving primary school students' mathematical problem-solving ability: A longitudinal experimental study. *Curriculum, Teaching Material and Method*, 43(10), 97–104. <https://doi.org/10.19877/j.cnki.kcjcf.2023.10.005>
- Hmelo-Silver, C. E. (2004). Problem-Based Learning: What and How Do Students Learn? *Educational Psychology Review*, 16(3), 235–266. <https://doi.org/10.1023/B:EDPR.0000034022.16470.f3>
- Hung, W. (2015). Problem-based learning: Conception, practice, and future. In Y. H. Cho, I. S. Caleon, & M. Kapur (Eds.), *Authentic problem solving and learning in the 21st century* (pp. 75–92). Springer. https://doi.org/10.1007/978-981-287-521-1_5
- Jiang, P., & Zhang, W. (2025). An investigation of creative thinking in mathematics textbooks: A comparative study of junior secondary textbooks in China and Singapore. *Journal of Mathematics Education*, 34(1), 37–44.
- Juandi, D., & Tamur, M. (2021). The impact of problem-based learning toward enhancing mathematical thinking: A meta-analysis study. *Journal of Engineering Science and Technology*, 16(4), 3548–3561.
- Karwowski, M. (2008). Measuring creativity using the test of creative imagination (TCI). Part 2: On validity of the TCI. *The New Educational Review*, 15(2), 216–231.
- Lai, C. L., & Hwang, G. J. (2016). A self-regulated flipped classroom approach to improving students' learning performance in a mathematics course. *Computers & Education*, 100, 126–140. <https://doi.org/10.1016/j.compedu.2016.05.006>
- Li, L. (2023). Teaching research on cultivating high school students' physics problem-solving abilities based on the PBL approach. Master thesis in Subject Teaching (Physics), School of Physics and Electronic Engineering, Henan University.
- Liu, J. (2022). A comparative analysis of two practical models of inquiry-based learning. *Shanghai Educational Research*, (2), 65–70. <https://doi.org/10.16194/j.cnki.31-1059/g4.2022.02.004>
- Ministry of Education of the People's Republic of China. (2022). *Mathematics curriculum standards for compulsory education* (2022 ed.). Beijing Normal University Press.

- National Council of Teachers of Mathematics. (2000). Principles and standards for school mathematics. NCTM.
- OECD. (2013). PISA 2012 assessment and analytical framework: Mathematics, reading, science, problem solving and financial literacy. OECD Publishing. <https://doi.org/10.1787/9789264190511-en>
- Savery, J. R. (2015). Overview of problem-based learning: Definitions and distinctions. In A. Walker, H. Leary, C. E. Hmelo-Silver, & P. A. Ertmer (Eds.), Essential readings in problem-based learning: Exploring and extending the legacy of Howard S. Barrows (pp. 5–15). Purdue University Press. <https://doi.org/10.2307/j.ctt6wq6fh.6>
- Siregar, N., Fauzi, K. M. A., & Syahputra, E. (2020). The effect of problem-based learning on students' mathematical creative thinking ability and self-efficacy. *Journal of Physics: Conference Series*, 1462(1), 012040. <https://doi.org/10.1088/1742-6596/1462/1/012040>
-