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Mathematical Creative Thinking Skills of Junior High School Students in a Problem-Based Learning Model Featuring Open-Ended Problems Viewed from Mathematics Anxiety

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Abstract
This study aims to (1) determine the classical mastery of mathematical creative thinking skills, (2) examine whether the students' average mathematical creative thinking skills exceed the minimum mastery criteria (KKTP), (3) assess the improvement in students' mathematical creative thinking skills, and (4) describe students' mathematical creative thinking skills in terms of mathematics anxiety. This study employed a mixed-methods approach with a sequential explanatory design. The research population comprised seventh-grade students at SMP Negeri 10 Semarang during the 2025/2026 academic year. The results indicated that (1) the implementation of the PBL model featuring open-ended problems achieved classical learning mastery, (2) the students' average mathematical creative thinking skills surpassed the minimum mastery criteria, (3) the improvement in mathematical creative thinking skills was in the moderate category with an N-Gain score of 0.6577, and (4) students with low mathematics anxiety met all indicators of mathematical creative thinking skills, students with moderate mathematics anxiety met most of the indicators, whereas students with high mathematics anxiety only met some indicators of mathematical creative thinking skills.

Keywords: *mathematical creative thinking skills; mathematics anxiety; open-ended problems; problem-based learning*

INTRODUCTION

Mathematical creative thinking is one of the higher-order thinking skills that needs to be developed in mathematics education. This skill plays a vital role in helping students generate various ideas, discover alternative solutions, and utilize diverse strategies when solving mathematical problems. Mathematical creative thinking skills comprise four indicators: fluency, flexibility, originality, and elaboration (Serevina et al., 2018). These skills are among the essential competencies required in 21st-century learning as they encourage students to think flexibly, innovatively, and adaptively when facing various problems (Kasse & Atmojo, 2022). Nevertheless, the Programme for International Student Assessment (PISA) results indicate that the creative thinking skills of Indonesian students still need improvement, necessitating instructional approaches capable of facilitating their development (OECD, 2024).

In addition to being influenced by the learning process, mathematical creative thinking skills are also affected by affective factors, one of which is mathematics anxiety. Mathematics anxiety is a feeling of fear, worry, or tension when students encounter activities related to mathematics (Cavanagh & Sparrow, 2010). A high level of anxiety can hinder concentration, reduce self-confidence, and cause students to be reluctant to try various problem-solving strategies. Conversely, students with low mathematics anxiety tend to be more confident in expressing ideas, exploring alternative solutions,

and solving problems more flexibly. Therefore, mathematics anxiety is considered one of the factors that must be addressed in developing mathematical creative thinking skills.

Based on the researcher's observations and interviews with a seventh-grade mathematics teacher at SMP Negeri 10 Semarang, it was revealed that the students' mathematical creative thinking skills remain relatively low. Students tend to solve problems by following the examples provided by the teacher and experience difficulties when faced with problems that have more than one solution method or multiple correct answers. The Mid-Semester Assessment (ATS) results also indicated that some students have not yet achieved the predetermined minimum mastery criteria (KKTP). This condition suggests that the instructional process still needs to be directed toward activities capable of encouraging students to think more creatively.

One instructional model that can facilitate the development of mathematical creative thinking skills is Problem-Based Learning (PBL). The PBL model utilizes contextual problems as the starting point of learning, thereby encouraging students to conduct investigations, engage in discussions, and construct knowledge through the problem-solving process (Rizal et al., 2025). The effectiveness of this model can be reinforced through the use of open-ended problems, as these problems provide students with the opportunity to generate various strategies and alternative correct answers (Prasetyo et al., 2023). Thus, the implementation of the PBL model featuring open-ended problems is expected to develop mathematical creative thinking skills while simultaneously mitigating the obstacles experienced by students due to mathematics anxiety.

The research questions in this study are: (1) do the mathematical creative thinking skills of junior high school students through the Problem-Based Learning model featuring open-ended problems achieve classical mastery?, (2) do the students' average mathematical creative thinking skills exceed the minimum mastery criteria (KKTP)?, (3) is there an improvement in mathematical creative thinking skills after participating in the Problem-Based Learning model featuring open-ended problems?, and (4) how are the students' mathematical creative thinking skills described based on the categories of high, moderate, and low mathematics anxiety?

METHOD

This study employed a mixed-methods approach. The research design utilized was a sequential explanatory design, a framework that begins with the collection and analysis of quantitative data, subsequently followed by the collection and analysis of qualitative data to further elaborate on the quantitative findings (Creswell, 2018). The research was conducted at SMP Negeri 10 Semarang during the even semester of the 2025/2026 academic year. The research population comprised all seventh-grade students at SMP Negeri 10 Semarang. The quantitative research sample consisted of 31 students from class VII-H, determined using a cluster random sampling technique. In the qualitative phase, six students were selected as research subjects using a purposive sampling technique, consisting of two students with high mathematics anxiety, two students with moderate mathematics anxiety, and two students with low mathematics anxiety.

The research data sources were obtained from a mathematical creative thinking skills test, a mathematics anxiety questionnaire, and interviews. Prior to the instruction, the students completed the mathematics anxiety questionnaire to categorize their levels of mathematics anxiety. Following the instruction using the Problem-Based Learning (PBL) model featuring open-ended problems, the students completed the mathematical creative thinking skills test. The six students representing each mathematics anxiety category were subsequently interviewed to obtain more in-depth information regarding their mathematical creative thinking skills as a form of data triangulation. Quantitative data were analyzed using a normality test, a classical mastery test, a one-sample t-test, and an improvement test (N-Gain). Qualitative data analysis included data reduction, data display, and conclusion drawing. The validity of the data was established through methodological triangulation by comparing the results of the mathematical creative thinking skills test with the interview results (Sugiyono, 2023).

RESULTS AND DISCUSSION

The research data were analyzed to determine the students' mathematical creative thinking skills through the implementation of the Problem-Based Learning (PBL) model featuring open-ended problems. The analysis included a classical mastery test, an average score test, an improvement test (N-Gain), and an analysis of mathematical creative thinking skills based on mathematics anxiety.

Table 1. Quantitative Data Results

Analysis	Result	Criteria
Classical mastery	90,32%	Mastered
Average score test	85,77>KKTP	Met
N-Gain	0,6577	Moderate

Based on the calculation of the classical mastery using a proportion test, a mastery percentage of 90.32% was obtained. The test results indicated that $z_{calculated} = 1.97 \geq z_{table} = 1.67$ at a 5% significance level; thus, H_0 was rejected and H_1 was accepted. Therefore, it can be concluded that the proportion of students whose mathematical creative thinking skills achieved the minimum mastery criteria (KKTP) exceeded the classical mastery threshold.

The average score test was utilized to determine whether the students' average mathematical creative thinking skills after participating in the instruction using the Problem-Based Learning (PBL) model featuring open-ended problems had surpassed the minimum mastery criteria (KKTP). Based on the results of the average score test, a value of $t_{calculated} = 4.423 > t_{table} = 1.697$ was obtained at a 5% significance level, meaning H_0 was rejected and H_1 was accepted. Hence, it can be concluded that the students' average mathematical creative thinking skills were higher than the KKTP. The improvement in mathematical creative thinking skills was analyzed using the N-Gain test. The calculation results showed an N-Gain score of 0.6577, which falls into the moderate category. These results indicated that the application of the Problem-Based Learning (PBL) model featuring open-ended problems was capable of improving students' mathematical creative thinking skills following the instruction.

The students' mathematical creative thinking skills after participating in the Problem-Based Learning (PBL) model featuring open-ended problems achieved a classical mastery of 90.32%, obtained an average that surpassed the KKTP, and experienced an improvement with an N-Gain score of 0.6577, which is categorized as moderate. These achievements were supported by an instructional process that provided students with the opportunity to understand problems, engage in discussions, conduct investigations, and propose various ideas and problem-solving strategies through open-ended problems. This process encouraged students to develop their mathematical creative thinking skills across the indicators of fluency, flexibility, originality, and elaboration. Subsequently, an analysis of mathematical creative thinking skills based on mathematics anxiety categories was conducted. The analysis results revealed differences in the achievement of mathematical creative thinking skill indicators across each mathematics anxiety category.

Table 2. Qualitative Data Results

Anxiety Category	Analysis Results
Low	Met all indicators of mathematical creative thinking skills
Moderate	Met most indicators of mathematical creative thinking skills
High	Met some indicators of mathematical creative thinking skills

Students with low mathematics anxiety were able to meet all indicators of mathematical creative thinking skills. For the fluency indicator, students were able to generate ideas or answers corresponding to the given problems. For the flexibility indicator, students could employ more than one problem-solving strategy, thereby demonstrating flexible thinking skills. For the originality indicator, students were able to provide unique solutions rather than merely following the provided examples. Furthermore, for the elaboration indicator, students were able to outline the problem-solving steps sequentially and clearly, making the provided answers easy to understand. These results indicate that students with low mathematics anxiety possess strong self-confidence in exploring various alternative solutions and optimally developing mathematical ideas. The following is the work of a student with low mathematics anxiety.

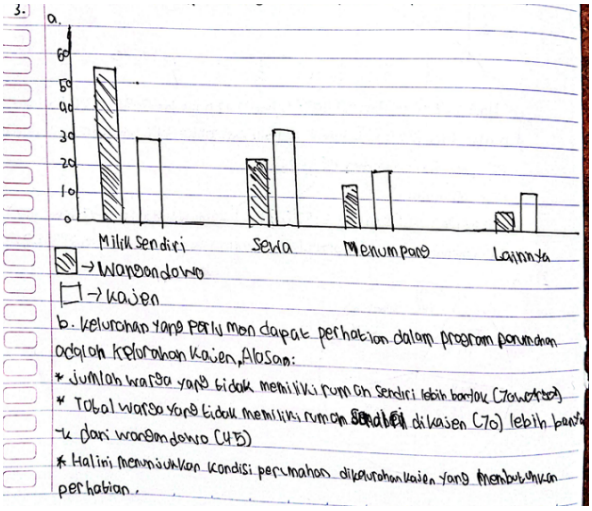

Figure 1. Answer Sheet of a Student with Low Mathematics Anxiety

Students with moderate mathematics anxiety demonstrated fairly good mathematical creative thinking skills, although they were not yet optimal across all indicators. For the fluency indicator, students were able to generate answers corresponding to the problems and complete all the given questions. For the flexibility indicator, students utilized a single correct problem-solving strategy but had not yet demonstrated alternative methods for solving the problems. For the originality indicator, the provided solutions still followed commonly used procedures, thus not yet exhibiting different or unique ideas. Meanwhile, for the elaboration indicator, students were able to write down the problem-solving steps sequentially, accompanied by calculations and conclusions, although the explanations provided were still simple and had not been developed in greater detail. These results indicate that students with moderate mathematics anxiety already have a solid understanding of the learned concepts but still require encouragement to explore more varied problem-solving strategies and develop more creative ideas.

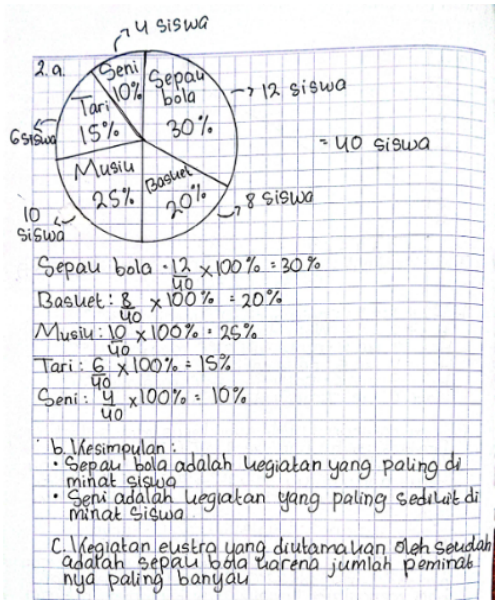

Figure 2. Answer Sheet of a Student with Moderate Mathematics Anxiety

Students with high mathematics anxiety exhibited limited mathematical creative thinking skills. For the fluency indicator, students were able to present answers according to the information in the problem, namely drawing a graph and explaining the daily temperature changes. For the flexibility indicator, students only used one problem-solving strategy and did not demonstrate alternative methods for solving the problems. For the originality indicator, the given answers still followed general

procedures, thus not yet demonstrating different ideas or solutions. For the elaboration indicator, students had written down the problem-solving steps and conclusions, but the provided explanations were still simple and did not elaborate on the information in detail. These results indicate that students with high mathematics anxiety have understood the basic concepts learned but still experience difficulties in developing ideas, utilizing varied strategies, and elaborating on solutions in greater depth.

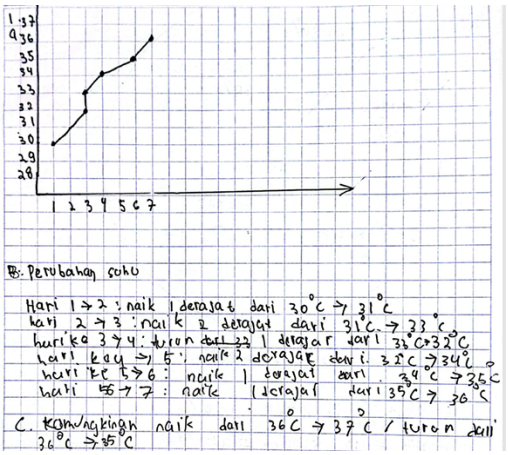

Figure 3. Answer Sheet of a Student with High Mathematics Anxiety

CONCLUSION

Based on the results and discussion, it can be concluded that the students' mathematical creative thinking skills through the implementation of the Problem-Based Learning (PBL) model featuring open-ended problems achieved a classical mastery of 90.32%, with the average mathematical creative thinking skills exceeding the minimum mastery criteria (KKTP). Furthermore, the application of the PBL model featuring open-ended problems was able to improve the students' mathematical creative thinking skills with an N-Gain score of 0.6577, which falls into the moderate category. The mathematical creative thinking skills also revealed differences across each mathematics anxiety category. Students with low mathematics anxiety were able to meet all indicators of mathematical creative thinking skills, students with moderate mathematics anxiety met most of the indicators, whereas students with high mathematics anxiety only met some indicators of mathematical creative thinking skills.

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