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META ANALYSIS: UTILIZING PROBLEM-BASED LEARNING FOR ENHANCING CREATIVE MATHEMATICAL THINKING ABILITIES

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Abstract

The ability to think creatively in a mathematical context is essential for students in the 21st century. In a global creativity survey carried out in 2015 by the Martins Prosperity Index, Indonesia was positioned 115th among 139 countries, with a score of 0.202, included in low category. One strategy to address this issue is by nurturing students' creative thinking skills in mathematics education. One exciting option for teaching is Problem-based Learning. This study aims to reevaluate how the Problem-based Learning approach can improve students' creative thinking skills in mathematics, building on existing research findings. The research method employed is meta-analysis, which involves the following steps; (1) formulate the topic; (2) overall study design; (3) sampling; (4) data collection; and (5) data analysis. Based on the results of the study, an average effect size of 1,057 was obtained in the high category. Meanwhile, based on the t-test enhancement test, obtained $t_{value} = 17{,}020 \geq t_{table} = 1{,}648$. In conclusion, the average performance of classes utilizing Problem-based Learning is higher than that of classes using other models.

Keywords: problem-based learning, mathematics, creative thinking

Abstrak

Kemampuan berpikir kreatif dalam konteks matematika menjadi esensial bagi siswa di era abad ke-21. Berdasarkan hasil survei kreativitas global oleh Martins Prosperity Index pada tahun 2015, Indonesia menempati peringkat 115 dari 139 negara dengan skor 0,202 yang termasuk dalam kategori rendah. Salah satu cara untuk menghadapi tantangan ini adalah dengan meningkatkan kemampuan siswa dalam berpikir kreatif selama pembelajaran matematika. Problem-based Learning merupakan model pengajaran yang dapat dimanfaatkan. Tujuan dari penelitian ini adalah untuk meninjau ulang penerapan model Pembelajaran Berbasis Masalah terhadap peningkatan kemampuan berpikir kreatif dalam matematika, dengan merujuk pada temuan penelitian sebelumnya. Metode penelitian yang digunakan yaitu meta analisis dengan langkah-langkah; (1) memformulasikan topik; (2) desain studi secara keseluruhan; (3) pengambilan sampel; (4) pengumpulan data; dan (5) analisis data. Berdasarkan hasil penelitian, diperoleh rata-rata effect size sebesar 1,057 dengan kategori tinggi. Sedangkan berdasarkan uji peningkatan t-test, diperoleh $t_{hitung} = 17{,}020 \geq t_{tabel} = 1{,}648$. Dapat disimpulkan bahwa rata-rata nilai kelas yang menerapkan Pembelajaran Berbasis Masalah lebih tinggi dibandingkan dengan rata-rata nilai kelas yang menggunakan model pembelajaran lainnya.

Kata kunci: problem-based learning, matematika, berpikir kreatif

INTRODUCTION

The capacity for creative thinking is an crucial competency that students need to have to address real-world challenges. All mathematical problems faced by students should be solved creatively in ways, ideas, or ideas that are able to answer existing problems. Furthermore, The ability for creative thinking is among the aptitudes that mark the beginning of the 21st century. As well as Zakiah et al. (2020); Septikasari (2018); Mardhiyah et al. (2021) It was elaborated that skills pertinent to the 21st century encompass creative, critical,

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communicative, and collaborative thinking abilities, which are instrumental in addressing real-life challenges.

The ability to think creatively, according to Febrianingsih (2022) and Darwanto (2019), is an ability related to sensitivity to a problem, expressing ideas or solutions different from an open mind in analyzing and solving problems, and resulting relationships in solving a problem. Each student needs to foster their creative thinking skills in order to grasp complex problems, then generate various perspectives, ideas, and ways to find solutions to complex problems. The ideas generated to solve problems are creativity or also called innovation. As argued by Suyitno (2020) and Acar et al. (2019), creativity that can produce new discoveries is often called innovation. Creativity, through the generation of inventive ideas and their transformation into innovations, serves as the cornerstone for attaining a competitive edge. The capability to think creatively in mathematics involves solving mathematical problems innovatively, fostering structured thinking, and offering ideas that are distinct or divergent from others (Amirulloh et al., 2020; Ramal et al., 2023).

According to the Martins Prosperity Index (2015) survey on the Global Creativity Index, Indonesia is ranked 115th out of 139th countries, with a score of 0.202, placing it in the low category. The reality that happened was not as expected. With the global creativity index owned by Indonesia, it indicates that Indonesia is still weak in terms of competitiveness and welfare, both of which are influenced by the creativity of its human resources. Thus, improvements are needed in increasing the creativity of human resources in Indonesia. One of the efforts can be done through learning mathematics.

Mathematical creativity at the school level is defined as the capacity for creative mathematical thinking. Dalilan & Sofyan (2022) contends that fostering creative thinking is a crucial skill that education in schools, particularly in mathematics learning, should prioritize. Cultivating mathematical creative thinking skills necessitates the involvement of multiple stakeholders, with teachers playing a pivotal role in classroom instruction. Assessing the ability for creative mathematical thinking requires the use of measurement tools or indicators of ability. In the research by Rasnawati et al. (2019) and Patmawati et al. (2019) about improving mathematical creativity, its used four indicators including fluency, flexibility, originality, and elaboration.

The four indicators of creative thinking ability are then explained by Hendriana et al. (2017) as follows.

1. Fluency of thinking, which refers to the skill of producing numerous ideas and diverse solutions seamlessly when tackling problems.
2. Flexibility of thinking, namely the ability to come up with ideas, solutions or various problems, able to identify problems from different perspectives, find alternative solutions to different problems, and able to use thinking with varied approaches.
3. Elaboration of thinking, namely the ability to grow ideas and add a solution to a problem in more detail and detail so that the idea or problem solution becomes more perfect.
4. Originality of thinking, namely the ability to produce original or unique ideas that come from oneself.

Catarino et al. (2019) explained that mathematical creativity at the school level is generally related to problem solving. When students are faced directly with problems, students tend to solve problems independently with creative solutions and ideas because the process of finding information to solve these problems is student-centered (Astuti et al., 2018). Hence, it is crucial for students to possess creative thinking skills in mathematics to effectively solve mathematical problems.

Educators can choose to use Problem-based Learning methods in order to improve students' creative thinking abilities. This statement aligns with the findings of Maskur et al. (2020) and Wartono et al. (2018), It has been proposed that Utilizing Problem-based Learning can improve students' creativity in mathematics, especially when it comes to solving problems. In the same way as the perspective of Selfiani et al. (2022); Arifin et al. (2019); Istianah & Yunarti (2015), Problem-based Learning fosters the development of students' higher-order thinking skills and creative thinking abilities. Problem-based Learning involves designing learning experiences centered around problems, which requires students to acquire fundamental knowledge, hone problem-solving abilities, and nurture their own learning strategies (Aminy et al., 2021). By engaging in Problem-based Learning, students are directly confronted with mathematical problems, prompting them to seek out data or information and utilize their creative thinking abilities to solve them (Septian & Rizkiandi, 2017).

Problem-based Learning offers chances for students to develop their capacity for creative thinking (Ugi, 2019; Ramadhani et al., 2020). This is because with Problem-based Learning, students will be faced directly with real problems whose solving process requires concentration on students. Therefore, Problem-based Learning can be utilized to address mathematical problems using ideas or solutions stemming from students' ability to think creatively in mathematics.

Research on the use of Problem-based Learning to enhance mathematical creative thinking skills was conducted by Septian & Rizkiandi (2017) also yielded similar results. The findings indicated a significant enhancement in these abilities through Problem-based Learning. As well as Aminy and associates. In a study conducted in 2021, researchers investigated the influence of Problem-based Learning on students' mathematical creative thinking abilities. The findings demonstrated that students who engaged in Problem-based Learning had higher levels of creative thinking in mathematics than students who received instruction using more conventional techniques. Therefore, the objective of this study is to evaluate the efficiency of Problem-based Learning in enhancing mathematical creative thinking abilities, drawing upon insights from various prior studies.

METHODS

This study uses a Meta Analysis method. Retnawati et al. (2018) explained that meta analysis is research using existing studies and has been used by other researchers carried out systematically and quantitatively to obtain accurate conclusions. Meta analysis collects studies with relevant topics. The stages of meta analysis according to Anadiroh (2019) are:

1. Formulate topics: The subject of this research focuses on employing Problem-based Learning models to enhance mathematical skills of student, specifically targeting their creative thinking ability in mathematics.
2. Overall study design: The study's population comprises students from both junior high school and high school levels.
3. Sampling: The sample used in this study varies in each article studied. The total sample was 239 experimental class students and 234 control class students.
4. Data collection: The data collection process for this study involved searching for online articles about Utilizing Problem-based Learning to improve skills in creative mathematical

thinking. Among the numerous articles reviewed, seven employed experimental or quantitative methods, and one article adopted a mixed-methods approach, incorporating both qualitative and quantitative techniques.

5. Data analysis: A review was conducted on data gathered from various research articles, detailing the study's title, researchers involved, research findings in terms of post-test values and standard deviations, and samples taken from experimental and control groups. After obtaining the data, it is analyzed by determining the effect size, conducting a t-test to test the hypothesis, presenting the results in a narrative manner, and drawing conclusions.

The calculation of the Effect Size value is carried out to assess the extent of impact of a research variable. The following is the formula for calculating effect size with one group posttest only according to Becker & Park (2011):

$$ES = \frac{\bar{x}_E - \bar{x}_C}{SD_C}$$

Information:

ES : Effect Size

$\bar{x}_E$: The average scores of students in the experimental group

$\bar{x}_C$: The average scores of students in the control group

SD_C : The standard deviation of the control class

The Effect Size calculation results are analyzed according to the categories defined by (Cohen, 1998).

Table 1. Category of Effect SIze

Effect Size	Categories
$ES > 0{,}8$	High
$0{,}5 < ES \leq 0{,}8$	Medium
$0{,}2 \leq ES \leq 0{,}5$	Low

Moreover, in order to calculate the mean disparity between the experimental and control groups, a test was conducted using the following formula.

$$t_{value} = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

Information:

$\bar{x}_1$: The average test of students in the experimental group

$\bar{x}_2$: The average test of students in the control group

n_1 : The number of experimental group

n_2 : The number of control group

S_1^2 : The variance of experimental group

S_2^2 : The variance of control group

RESULTS AND DISCUSSION

This study utilizes 8 articles that align with the research problems, as determined by the search and data collection results. All collected articles address relevant topics and focus on the same two variables: Problem-based Learning and its influence on improving students' creative thinking abilities in mathematics. The papers were acquired from Google Scholar and Research Gate and were published between 2017 and 2022. One article was published in 2017 and 2020, while two articles were published in each of the years 2019, 2021, and 2022. Below are the findings from the analysis of 8 articles.

1. Ari Septian and Riki Rizkiandi’s (2017) research entitled "Application of the Problem-based Learning Model to Improve Students' Mathematical Creative Thinking Ability". Variances in the ultimate level of mathematical creative thinking proficiency were noted among students who received instruction through the Problem-based Learning method and those who were instructed using traditional methods. The variation arises from the efficacy of Problem-based Learning implementation in the classroom. Moreover, students in the experimental group exhibited more pronounced improvement in their mathematical creative thinking skills following instruction with Problem-based Learning, in contrast to those in the control group who underwent traditional teaching methods. Based on the analysis of students' mathematical creative thinking abilities, the experimental group had an average gain index score of 0.7374, with a standard deviation of 0.1830. Regarding the control group, an average of 0.3442 was recorded with a standard deviation of 0.2369.
2. Meiliza Aminy, Herizal, and Wulandari's (2021) research entitled "Application of Geogebra-Assisted Problem-based Learning Model to Improve Mathematical Creative Thinking Ability of Students of SMA Negeri 1 Muara Batu". Disparities in mathematical creativity were observed between students in the experimental and control classes both before and after they underwent the learning process. There was

an improvement in the average posttest scores of both the experimental and control classes. In particular, the experimental class, which used Problem-based Learning (PBL) with assistance from GeoGebra, had a higher average posttest score compared to the control class that used a scientific approach.

3. Selfiani, Tedy Machmud, Resmawan, and Yamin Ismail’s (2022) research entitled "The Effect of the Problem-based Learning Model on Students' Mathematical Creative Thinking Ability on Cube and Cuboid Material". It was determined that employing Problem-based Learning influenced students' capacity for creative thinking in mathematics, specifically with cube and block materials. Students enrolled in Problem-based Learning exhibit greater proficiency in creative mathematical thinking when compared to students following the direct learning approach. This is proven in a two-sample test with $t_{value} = 1{,}859$, $t_{table} = 1{,}684$ so that $t_{value} > t_{table}$.
4. Pinta Romaito, et al’s (2021) research entitled "The Mathematics Learning using Geogebra Software to Improve Students’ Creative Thinking Ability". According to the data analysis results of the final scores from the test or posttest measuring mathematical creative thinking ability, obtained from both the experimental and control classes, t_{value} is 0.004. Because $t_{value} \leq t_{table}$ that indicates that H_0 is accepted and H_a is rejected. The conclusion drawn was that students' that use Problem-based Learning with the assistance of Geogebra Software has a better proficiency in mathematical creative thinking that of students using traditional learning models.
5. La Eru Ugi’s (2019) research entitled "The Effect of Problem-based Learning Models on Students' Creative Thinking Ability". The experimental group achieved an average posttest score of 85.79, while the control group had an average posttest score of 44.74. Within the Problem-based Learning model, creative students exhibited a higher capability for mathematical thinking compared to their counterparts in the direct learning model.
6. Trisna Rukhmana's (2022) research entitled "The Effect of the Problem Based Learning Model on Students' Mathematical Creative Thinking Ability in Mathematics Learning in Class VIII". The utilization of Problem-based Learning on the Pythagorean Theorem material in the experimental group was noted to enhance students'

mathematical creative thinking abilities, resulting in an average score of 9.2272, $S = 1.4146$, and $S^2 = 2.0011$.

7. Rahmi Ramdahani, Fajri Farid, Fitria Lestari, and Amir Mahmud's (2020) reseach entitled "Improvement of Creative Thinking Ability through Problem-based Learning with Local Culture based on Students' Gender and Prior Mathematics Ability". The results showed that students who participated in Problem-based Learning demonstrated better mathematical problem-solving abilities than those who received direct instruction. Problem-based Learning has also shown the ability to improve students' cognitive skills. Moreover, it was pointed out that utilizing Problem-based Learning led to notable improvements in student performance in the classroom.
8. Research by Ririn Prihantini, Azin Taufik, and Mohamad Riyadi (2019) entitled "Application of Tangram Media-Assisted Problem-based Learning Model to Improve Students' Mathematical Creative Thinking Skills". The data shows that, the standard deviation of the experimental class was 12.325 with an average score of 67.97, ranging from 44 to 91. In comparison, the control class had a standard deviation of 14.194, an average score of 55.66, and scores ranging from 27 to 86. There exists a variance in the progression of students' mathematical creative thinking between classes solely employing Problem-based Learning and those incorporating Tangram media support alongside it.

Here are the effect size values of each article.

Table 1. The Effect Size Value of Each Article

Code	Experimental Class			Control Class			Combined SD	Effect Size	Category
	The Number of Sample	Average of Posttest	SD Posttest	The Number of Sample	Average of Posttest	SD Posttest			
Z1a	39	78,33	15,06	34	49,26	17,93	16,45	1,621	High
Z2a	31	47,84	6,91	31	38,50	4,69	5,91	0,935	High
Z3a	20	89,60	10,74	20	77,40	10,31	10,53	0,592	Medium
Z4a	30	75,00	7,78	30	68,00	8,12	7,95	0,862	High
Z5a	19	85,79	12,06	19	44,74	14,33	13,24	1,719	High
Z6a	35	76,89	1,41	35	67,05	1,19	1,31	0,996	High
Z7a	30	77,35	1,65	30	70,10	1,68	1,67	0,863	High
Z8a	35	67,97	12,33	35	55,66	14,19	13,29	0,867	High
		x̄=74,85	SD=9,74		x̄=58,84	SD=10,7			

The t-test calculation is performed to determine whether there exists a disparity in the means between the experimental and control groups, as outlined below.

Determining the Hypothesis

$H_0: \mu_1 < \mu_2$ (The average test of the class using Problem-based Learning is less than or equal to the average test of the class using other learning model)

$H_1: \mu_1 \geq \mu_2$ (The average test of the class using Problem-based Learning is more than the average test of the class using other learning model)

Determining t_{table} $(\alpha = 0{,}05)$

$$df = n_1 + n_2 - 2 = 239 + 234 - 2 = 471$$

$$t_{table} = t_{0{,}05{,}471} = 1{,}648$$

Determining $\mathrm{t_{value}}$

$$t_{value} = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

$$t_{value} = \frac{16{,}01}{0{,}9405}$$

$$t_{value} = 17{,}020$$

Decision Making Criteria

The decision criteria is, $\mathrm{H_0}$ is accepted if $t_{value} < t_{table}$ and $\mathrm{H_0}$ is rejected if $t_{value} \geq t_{table}$. Obtained that $t_{value} = 17{,}020 \geq t_{table} = 1{,}648$ so $\mathrm{H_0}$ is rejected. Therefore, it can be inferred that the average test scores of students in a class using Problem-based Learning are higher compared to those using other learning models.

Drawing from the data presented in table 2, which contains posttest data, standard deviation, many samples, effect size calculation analysis is carried out. It was found that of the 8 articles studied, 7 of them had an effect size value with a high category, while 1 other aricle had an effect size value with a medium category. In general, the significant effect size indicates that Problem-based Learning has a noteworthy impact on enhancing mathematical creative thinking skills.

After conducting calculations to test the hypothesis, it was found that the t_{value} is 17,020 while t_{table} is 1,648. Then because $t_{value} = 17{,}020 \geq t_{table} = 1{,}648$ so H_0 is rejected. The conclusion drawn is that the average of the experimental class surpasses that of the control class. These results align with previous studies by Maskur et al. (2020) and Wartono et al., as indicated by this meta-analysis. In 2018, it was asserted that the adoption of Problem-based Learning had the potential to enhance students' aptitude for creative thinking in mathematics, especially concerning the resolution of mathematical problems.

Additionally, a study by Septian & Rizkiandi (2017) found that implementing Problem-based Learning can lead to a noteworthy improvement in mathematical creative thinking skills. Likewise, a study conducted by Aminy and colleagues. In 2021, a research study investigated how Problem-based Learning influenced the mathematical creative thinking skills of students. The findings revealed that students who engaged in Problem-based Learning exhibited elevated levels of creativity in mathematics compared to those who adhered to conventional teaching methods. Overall, the analysis of eight national and international articles in this study corroborated that Problem-based Learning effectively enhances creative thinking skills in mathematics. Furthermore, when juxtaposed with alternative learning models, Problem-based Learning was found to foster higher levels of mathematical creative thinking.

CONCLUSION

After scrutinizing numerous articles, It was noted that the Problem-based Learning approach significantly boosts students' creative thinking skills in mathematics, as indicated by a notable effect size value. This is further supported by the results of t-test calculations, which showed a $t_{value} = 17{,}020 \geq t_{table} = 1{,}648$ so H_0 is rejected. This indicates that the experimental group outperforms the control group in terms of proficiency. In conclusion, it can be inferred that Problem-based Learning improves students' mathematical creative thinking abilities. Moreover, students engaged in Problem-based Learning exhibit higher levels of mathematical creative thinking abilities compared to those using other learning models.

Research conducted with Problem-based Learning strategies centered on cube and cuboid materials in junior high school settings produced moderate effect sizes, bordering on the lower end of the spectrum. This suggests that Problem-based Learning has a limited impact on improving creative thinking skills in mathematics. Hence, it is recommended that other researchers undertake further investigation into the application of Problem-based Learning with cube and cuboid materials in junior high school environments.

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