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Meta-Analysis of the Influence of Problem-Based Learning (PBL) Learning Model on the Improvement of Creative Thinking Skills

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ABSTRACT:

Learning mathematics is an essential aspect of education, from elementary to tertiary levels. One effective method of teaching mathematics is Problem Based Learning (PBL). To determine the extent of the influence of implementing the PBL method on creative thinking skills in mathematics, the author collected 86 articles from various sources such as Google Scholar, Portal Garuda, and Sintaristekbrin. This study used a meta-analysis method to combine the findings from these articles. After analyzing all the collected articles, only 10 articles met the inclusion criteria and were analyzed using the meta-mar website to measure the combined effect of PBL implementation. Based on the interpretation of the combined effect size, it can be concluded that overall, the implementation of PBL has a moderate influence on mathematics learning by enhancing creative thinking skills. The study also examined factors such as educational level, year of research, region, and sample size used in the studies. Based on statistical analysis, the research indicated that the application of PBL to students' creative thinking skills is influenced by these factors, such as educational level, year of research, and sample size.

Keywords: Meta-Analysis, Problem Based Learning, Creative Thinking

Introduction:

The impact of globalization has a broad influence on various aspects of community life. Basic skills such as reading, writing, and arithmetic are no longer sufficient for students to compete in this challenging era. Therefore, education in the 21st century must be able to prepare and equip students to compete in the global society. Every individual living in the 21st-century reform era is expected to possess four key skills: critical thinking skills, creative thinking skills, communication skills, and collaboration skills(1). This aligns with the opinion of (2). The importance of having critical and creative thinking skills is strongly emphasized today. With the rapid advancement of science and technology, access to information has become easier and more abundant from various sources. This results in rapid changes in global life and situations. Without critical and creative thinking skills, individuals will not be able to process, evaluate, and use the necessary information to face these challenges. Therefore, critical and creative thinking skills are crucial in everyday life.

Creative thinking involves mental activities that require persistence, discipline, and attention. These mental activities include things like asking questions, opening the mind to new information and unconventional ideas, building connections between different things, associating freely, using imagination in various situations to generate different outcomes, and listening to intuition. The ability to think creatively is crucial for students as it is a part of life skills necessary for the advancement of science and technology(3).

Creative thinking involves divergent thinking encompassing aspects of fluency, flexibility, originality, and elaboration. Fluency is the mental process that enables us to generate a large number of ideas smoothly and without obstacles. Flexibility is a thinking ability that allows an individual to view and present various different perspectives flexibly and creatively. Originality is the thinking ability that enables an individual to produce new and unusual ideas. Elaboration is the thinking ability that involves using detailed and intricate ways to refine and develop ideas (4).

The learning model plays a crucial role in developing students' creative thinking skills. One widely used learning model is Problem Based Learning (PBL). Problem Based Learning (PBL) is a teaching approach where learners utilize real-world problems to hone their creative mathematical thinking skills (5). They independently learn by seeking innovative solutions and applying mathematical concepts to real-life contexts. PBL helps learners become more independent in their learning and develop critical, analytical, and collaborative thinking skills, which are essential in both mathematics and everyday life(6).

The previous research conducted by (7) in the 8th grade of SMP Negeri 6 Lubuklinggau indicated that PBL can have a positive impact on improving students' creative thinking abilities. In the PBL environment, students are exposed to real-life situations that require creative thinking, collaboration, and self-reflection. However, despite initial evidence suggesting a positive relationship between PBL and creative thinking abilities, further research is still needed to gain a deeper understanding of the influence of this learning model. It is essential to examine variables that affect students' learning outcomes in the context of PBL, such as the role of educators, task design, student engagement, and technological support. With a better understanding of the

relationship between PBL and creative thinking abilities, educators and educational practitioners can optimize the use of this learning model to enhance student learning and development.

Through conducting this meta-analysis, it is expected to provide a deeper understanding of the potential of Problem-Based Learning (PBL) as an effective learning approach in developing students' mathematical abilities. The results of this article are anticipated to offer a better understanding of the relationship between PBL and creative thinking abilities. With this enhanced understanding, educators and educational practitioners can optimize the use of this learning model to improve student learning and development.

Methodology:

This research employs a meta-analysis method involving the review of articles published in national journals. Meta-analysis is a statistical method used to systematically combine, analyze, and synthesize multiple studies to obtain the latest findings and conclusions based on the study effects. According to stages in meta-analysis include determining inclusion criteria for the studies to be analyzed, empirical data collection procedures, explaining how variables in the studies are coded, and detailing the statistical techniques used. In this study, articles from relevant primary studies on the Problem-Based Learning (PBL) model in enhancing students' creative thinking abilities were selected based on predefined inclusion criteria.

In the meta-analysis covering the publication years 2015 to 2022, the following inclusion criteria were established:

1. The articles must be conducted in the context of research in Indonesia.
2. The articles must be published in journals indexed by SINTA.
3. The articles must use quasi-experimental research methods with one of the following four designs: randomized control group pretest-posttest design, randomized control group posttest only design, nonequivalent group pretest-posttest design, or nonequivalent group posttest only design.
4. The primary study population in the articles should consist of students at the junior high school, senior high school, and university levels in Indonesia.
5. The articles must include statistical data from the primary studies, including sample size, mean, and standard deviation.

Considering the above inclusion criteria, articles that meet these criteria can be selected and included in the meta-analysis. After searching for articles using databases such as Google Scholar, Portal Garuda, and Sinta Ristekbrin with the keywords "Problem Based Learning, creative thinking" within the publication years 2015-2022, a total of 86 articles were found. Subsequently, articles were selected based on the established inclusion criteria. Finally, 10 articles were identified that met the inclusion criteria for junior high school (SMP/MTs) and senior high school (SMA/equivalent) as well as university levels. Therefore, there are 10 relevant articles for this research.

The next step is to conduct the study coding. This process involves using an instrument, such as a coding form on paper or a computer, along with a manual guide explaining the coding procedures for each item based on the data in the primary studies. The study coding includes information such as study code, authors, publication year, mean, standard deviation, and sample size for the experimental and control groups, as well as the educational level and year of the study. Once the coding process is complete, the next step is to calculate the effect size. In meta-analysis, the effect size used is the standardized mean difference (Hedges's g)(8). For interpreting the effect size, guidance provided by(9) can be consulted.

Formula for Hedges's g is as follows:

$$Hedges'g = \frac{M_1 - M_2}{SD^*pooled}$$

Explanation:

$M_1 - M_2$ = difference in means

$SD^*pooled =$ pooled and weighted standard deviation

Table 1. Interpretation of Effect Size

ES	Interpretasi ES
0 ≤ ES ≤ 0.20	Efek Lemah
0.20 < ES ≤ 0.50	Efek Sederhana
0.50 < ES ≤ 1.00	Efek Sedang
ES > 1.00	Efek Kuat

After calculating the effect size, the results can be used to proceed with further meta-analysis processes. The next step is to perform a homogeneity test to determine the analysis model to be used, using the p-value as a reference (Apriatni et al., 2022). If the p-value < 0.05, the data is considered

heterogeneous, and the analysis model used is the random-effects model. Conversely, if the p-value > 0.05, the data is considered homogeneous, and the analysis model used is the fixed-effects model (10).

To prevent inaccurate representation in the findings, a publication bias check is necessary. This is crucial to ensure that the results of the meta-analysis reflect objective findings and are not influenced by potential biases in the reviewed publications. Published studies are more likely to be included in a meta-analysis than unpublished studies, raising concerns that the meta-analysis may exaggerate the original effect size (11). To detect and address publication bias, methods such as funnel plots and Fail-Safe N (FSN) Rosenthal can be employed (10).

One initial method for detecting publication bias is using a funnel plot. If the distribution of study effect sizes is not symmetric or not fully symmetric, FSN Rosenthal is used to help determine the presence of publication bias (12). If the value of FSN / (5k + 10) > 1, with k being the number of studies in the meta-analysis, the study is considered to be resistant to publication bias (Mullen et al., 2001). If there is no indication of publication bias, the analysis process can proceed. Through the analysis model, the authors can test the null hypothesis (H0) (10). If the p-value < 0.05, H0 will be accepted. If the analysis model uses a random effect, indicating variation in study characteristics, the authors can analyze the study characteristics and interpret the analysis results (10).

Results

The objective of this study is to evaluate the combined effect size of implementing the Problem-Based Learning (PBL) model on students' creative thinking abilities. This research aims to gather data from various previously conducted studies to obtain a comprehensive understanding of the impact of implementing the PBL model on students' creative thinking abilities. The following is a list of studies included in this research:

Table 2. Studies used in the Meta-Analysis

Code	Title of Study	Year	Journal Name
Study 1	Keefektifan Model PBL Dengan Mind Map Melalui Hands On Activity Terhadap Kemampuan Berpikir Kreatif Siswa (https://journal.unnes.ac.id/sju/index.php/ujme/article/view/7602)	2015	Jurnal UJME
Study 2	Penerapan Model Problem Based Learning (PBL) Terhadap Peningkatan Kemampuan Berpikir Kreatif Matematis Siswa (https://jurnal.unsur.ac.id/prisma/article/download/22/14)	2017	Jurnal Prisma
Study 3	Efektivitas Problem Based Learning Terhadap Kemampuan Berpikir Kreatif Mahasiswa Program Studi Tadris Matematika UIN Mataram(https://doaj.org/article/0c204afc8bf3425fbaf9ee170e4a191d)	2017	Jurnal JTAM
Study 4	Penerapan Pendekatan Problem Based Learning Untuk Meningkatkan Kemampuan Berpikir Kreatif Matematik Siswa SMA (https://jurnal.umk.ac.id/index.php/anargya/article/view/4135)	2019	Jurnal Ilmiah Pendidikan Matematika
Study 5	Perbedaan Kemampuan Berpikir Kreatif Matematika antara Siswa yang Diajar Menggunakan Model Pembelajaran Problem Based Learning (PBL) dengan Pembelajaran Langsung(https://onesearch.id/Record/IOS15943.article-46)	2019	JMPM
Study 6	Penerapan Model Problem Based Learning Berbasis Budaya Industri Untuk Meningkatkan Kemampuan Berpikir Kreatif Matematis Siswa SMK (https://e-jurnal.lppmunsera.org/index.php/gauss/article/view/2720)	2020	Gauss: Jurnal Pendidikan Matematika,
Study 7	Penerapan Model Problem Based Learning Berbantuan Geogebra Untuk Meningkatkan Kemampuan Berpikir Kreatif Matematis Siswa SMA Negeri 1 Muara Batu (https://ojs.unimal.ac.id/jpmm/article/view/4390)	2021	Jurnal Pendidikan Matematika Malikussaleh
Study 8	The Effect of E-Learning Based on the Problem-Based Learning Model on Students' Creative Thinking Skills During the Covid-19 Pandemic(https://files.eric.ed.gov/fulltext/EJ1341621.pdf)	2022	International Journal of Instruction

Study 9	Pengaruh Model Pembelajaran Problem Based Learning Berbantuan Multimedia terhadap Kemampuan Berpikir Kreatif Siswa SMP (https://mail.jptam.org/index.php/jptam/article/view/5816)	2022	Jurnal Pendidikan Tambusai
Study 10	Efektivitas Penggunaan LKS Problem Based Learning (PBL) Materi Aritmatika Ditinjau dari Kemampuan Berpikir Kreatif Matematika (https://j-cup.org/index.php/cendekia/article/view/1119)	2022	Jurnal Cendekia

By using the meta-mar website, research data for each study according to Hedges's g is obtained in Table 3 below.

Table 3. Effect size, Interpretation of Effect Size, Standard Error, and Confidence Interval of Each Study

Study Code	**Author Publication**	**Year**	**Effect Size**	**Interpretation of Effect Size**	**SE**	**Confidence Interval**	
						Lower Bound	**Upper Bound**
Study 1	(Ramadhani et al., 2015)(13)	2015	1.7668	Strong Effect	0.2958	1.1870	2.3465
Study 2	(Septian & Rizkiandi, 2017)(14)	2017	1,7478	Strong Effect	0,2765	1,2059	2,2896
Study 3	(Fahrudin, 2017)(15)	2017	0,7104	Moderate Effect	0,2921	0,1378	1,2829
Study 4	(Nurjaman & Sari, 2019)(16)	2019	1,0155	Strong Effect	0,2795	0,4678	1,5633
Study 5	(Tamami et al., 2019)(17)	2019	1,5528	Strong Effect	0,2696	1,0245	2,0812
Study 6	(Yosi & Puput, 2020)(18)	2020	0,6157	Moderate Effect	0,2644	0.0975	1,1339
Study 7	(Aminy et al., 2021)(19)	2021	0,7324	Moderate Effect	0,2626	0,2177	1,2471
Study 8	(Yustina et al., 2022)(20)	2022	0,7635	Moderate Effect	0,3412	0,0948	1,4323
Study 9	(Deswita et al., 2022)(21)	2022	2,7593	Strong Effect	0,4352	1,9063	3,6123
Study 10	(Mahendrawan et al., 2022)(4)	2022	2,1020	Strong Effect	0,2869	1,5397	2,6642

Based on Table 3, there is a variation in effect sizes across studies, with 10 studies ranging from 0.6157 to 2.7593. Through the interpretation of effect size using Cohen's classification, it can be concluded that there are 6 studies with a strong effect size, indicating that the implementation of the PBL model in these studies has a strong impact on students' creative thinking abilities. Additionally, there are 4 studies with a moderate effect size, indicating that the implementation of the PBL model has a moderate impact on students' creative thinking.

To determine the overall effect size across all primary studies, the authors need to create an estimation model through testing the homogeneity of all studies. Table 4 provides information related to the homogeneity test of all primary studies.

Table 4. Heterogeneity of Effect Size Distributions

Heterogeneity				
Chi²	**Df**	**P-Value**	**I-squared**	**Tau²**
43,60	9	P < 0.01	79%	0.3727

Based on Table 4, there is a p-value < 0.05, indicating that the distribution of effect sizes in the primary studies is analyzed to be heterogeneous in nature. Therefore, an estimation model is used to determine the combined effect size with a random-effects model. Subsequently, publication bias is assessed using a funnel plot as shown below.

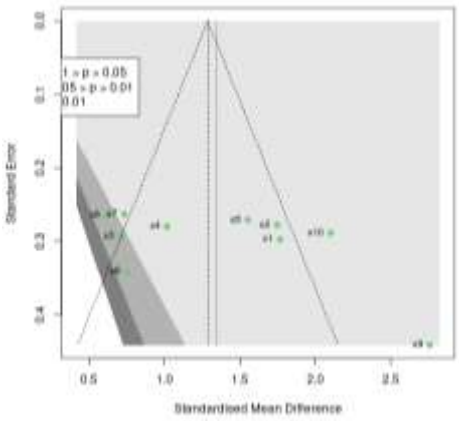

Fig 1. Funnel Plot

Based on Figure 1, the distribution of effect sizes in the studies is asymmetric. Therefore, the authors detect publication bias with a Fail-Safe N (FSN) of 697.71 from the observed studies (k) totaling 10. Using the formula:

$$\frac{FSN}{5k+10} = \frac{918}{5(12)+1} = 15{,}05 > 1$$

Conclusively, if studies in this meta-analysis exhibit sufficient tolerance to publication bias (Tamur et al., 2020). Furthermore, Table 5 presents the results of the meta-analysis from primary studies using fixed-effects and random-effects models.

Table 5. Meta-Analysis Results Based on Estimation Models

Models	**n**	**Effect Size and Convidence Interval**				**Test of null (2-Tail)**	
		Effect Size	**SE**	**Lower**	**Upper**	**Z-Value**	**P-Value**
Fixed Effect	10	1.2869	0,1793	1,1056	1,4683	13.91	0.0001
Random Effect	10	1.3481	0,501	0,8471	1,8491	6.09	0.0002

With the previous test of homogeneity in primary studies, there is a heterogeneous distribution of study effect sizes, thus the analysis is conducted using a random-effects model. From Table 5, in the random-effects model row, the p-value in the Z-test is 0.0002. Since p-value < 0.05, it is concluded overall that the use of the PBL model significantly influences students' creative thinking abilities. In the subsequent research, the combined effect size is found to be 1.3481, which, according to Cohen's classification, is considered a strong effect size. In conclusion, the overall implementation of the PBL model has a strong impact on students. Additionally, the combined effect size of 1.3481 implies that the mean mathematical creative thinking ability of 88% of students in the control group is influenced. As the distribution of the primary study effects is heterogeneous, an analysis of study characteristics is required to understand the heterogeneity in students' mathematical reasoning abilities. The results of the meta-analysis on various characteristics are presented in Table 6.

This is consistent with a study conducted by (5), which concludes that the mathematical problem-solving abilities of students learning through problem-based learning models are in a good qualification, and the problem-based learning model influences mathematical creative thinking abilities.

Table 6. Meta Analysis Results for Each Character Study

Characteristics Study	**Category**	**N**	**Hedges'g**	**P-value**	**95% CI**	
					Lower	**Upper**
Educational Level	SMP	5	1,89	0,17	1,40	2,39
	SMA	4	0,77	0,77	0,50	1,05
	Univ.	1	0,71	-	0,14	1,28
Year of Research	2015-2017	2	1,76	0,96	1,64	1,88

	2019-2021	5	0,93	0,09	0,45	1,40
	2022-2023	3	1,85	0,01	-0,67	4,38
Region	Java Island	5	1,44	0,01	0,68	2,21
	Outside Java Island	5	1,26	0,01	0,20	2,33
Sample Size	≥ 30	6	1,41	0,01	0,77	2,05
	< 30	4	1,27	0,01	0,85	1,85

Based on Table 6, regarding the characteristic of educational level, it is found that the effect size is strong for the junior high school (SMP) category, while for the senior high school (SMA) and university categories, the effect size is moderate. Additionally, the total between-group p-value in the heterogeneity section is 0.123. Since the p-value is < 0.05, the distribution of effects in both categories in the study characteristic is heterogeneous. Therefore, the conclusion is that the creative mathematical thinking ability of students through the implementation of the PBL model is influenced by the educational level, and the educational model is suitable for use in junior high school, senior high school, or university with a strong impact.

Regarding the study characteristics based on the year of research, it is found that the lowest effect size is in the years 2019-2021, classified as a moderate effect, while the high effect sizes are in the research years 2015-2017 and 2022-2023, categorized as strong effects. In other studies, the implementation of K-13 with the PBL model began in 2013-2014(22). There is a significant difference in the impact of applying the PBL model on students' mathematical reasoning abilities based on the research year, leading to the conclusion that the implementation of the PBL model for improving students' mathematical reasoning abilities is influenced by the research year. Low mathematics abilities of students are attributed to the use of methods.

For the study characteristics based on the region, it is found that the effect size in the Java and non-Java regions falls into the strong effect category. And for the study characteristics based on sample size, it is obtained that sample sizes less than 30 or more than 30 fall into the strong effect category. The mathematical creative thinking ability of grade XI IPA 2 students at SMA Negeri 1 Gomo, using problem-based learning or PBL, is classified as moderately creative (23).

Based on the research results on the implementation of the PBL model assisted by multimedia to improve creative thinking abilities, several conclusions can be drawn. First, the problem-solving ability of students using PBL-assisted multimedia learning has reached the level of classical completeness. Second, the creative thinking ability of students using PBL-assisted multimedia learning is better than students using expository learning. Third, there is a positive influence between creative thinking ability and problem-solving ability of students using PBL-assisted multimedia learning. In other words, the higher the creative thinking ability of students, the higher their problem-solving ability.

Conversely, the lower the creative thinking ability of students, the lower their problem-solving ability (24). The research conducted by (1) shows that after implementing learning using the Problem-Based Learning (PBL) model, students' mathematical communication abilities improve. The research results by (25) also show an improvement in students' mathematical communication abilities through the use of the PBL model.

Thus, the conclusion that can be drawn from these studies is that the implementation of the PBL model not only enhances students' critical and creative thinking abilities but also has a positive impact on students' mathematical communication abilities.

Conclusion

Based on the meta-analysis of 10 conducted studies, it was found that the combined effect size from the primary studies is 1.3481, classified as a strong effect according to Cohen's classification. Thus, it can be concluded that the use of the PBL model has a stronger impact on students' creative thinking abilities compared to traditional models. Traditional learning models typically have a teacher-centered approach, with students placed as objects in the learning process.

Moreover, the implementation of the PBL model also influences the improvement of students' creative thinking abilities, depending on various research characteristics such as the education level and the study year. These findings provide guidance for educators in utilizing the PBL model as an alternative learning method that can help enhance students' creative thinking abilities.

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