WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

The Influence of Problem-Based Learning (PBL) Model on Mathematical Critical Thinking Abilities: A Meta-Analysis

Syifaurrohmah Kusuma Edy [a], Syamsuri [b], Hepsi Nindiasari [c], Novaliyosi [d]*

[a,b,c,d] Sultan Ageng Tirtayasa University, Jl. Raya Palka Km 3 Sindangsari, Pabuaran, Kab. Serang Provinsi Banten, 42118, Indonesia
[a] SMAN 8 Kota Serang, l. Kalodran, Sindangraksa, Teritih, Kec. Walantaka, Kota Serang, Banten, 42183, Indonesia
Doi: https://doi.org/10.55248/gengpi.5.0624.1566

A B S T R A C T

One of the abilities that students need to have in learning mathematics is critical thinking. Problem Based Learning (PBL) is one of the teaching approaches that has been widely used in mathematics education. Through various sources such as Sinta and Garuda, the author managed to obtain 72 articles, which were then selected according to inclusion criteria to become 13 articles on the influence of PBL on critical thinking skills. These articles will be analyzed using the website https://www.meta-mar.com to obtain the combined effect size. Based on the analysis of the combined effect size, it can be concluded that overall, the implementation of PBL as a teaching model has a significant and strong influence on students' mathematical critical thinking abilities.

Keywords: Critical thinking, metanalysis, problem based learning, PBL.

1. Introduction

Mathematics education is one of the common and compulsory subjects in the curriculum of various countries. The primary goal of mathematics education is to develop students' critical thinking abilities, which are essential skills in problem-solving and decision-making (Rasiman, 2013). Mathematics plays a significant role in the advancement of science and technology. As a discipline, mathematics has a crucial role as a tool for applying mathematical principles to various other fields of science. Moreover, mathematics also plays a role in its own development as a continuously evolving branch of knowledge (Siagian, 2016).

Problem-Based Learning (PBL) or Pembelajaran Berbasis Masalah (PBM) is a learning approach that has been widely used in mathematics education (Sopiah, 2019). PBL (Problem-Based Learning) is a learning model that focuses on involving students in real-world problem-solving scenarios, encouraging active learning, and promoting critical thinking skills (Hidayati, 2013). Within the framework of PBL, the main focus is on an active and participatory learning approach, where students are not merely passive recipients of information but are actively involved in the learning process. PBL provides opportunities for students to engage in solving real problems that are relevant to their life context. In this context, students are encouraged to work collaboratively with their classmates, share knowledge, explore mutual understanding, and support each other. This collaborative process allows them to view problems from various perspectives and broaden their horizons. Furthermore, by adopting a proactive problem-solving approach, students are given opportunities to enhance their critical thinking skills (Yew & Goh, 2016).

Therefore, the researchers are interested in conducting a study aimed at performing a meta-analysis to examine the effect of the Problem Based Learning (PBL) model on students' mathematical critical thinking skills. By combining findings from various previous Studyes, this research aims to provide a comprehensive overview and robust findings on the impact of PBL on students' critical thinking abilities.

2. Method

This study adopts a meta-analysis approach by reviewing several articles published in national journals. Meta-analysis is a statistical method used to systematically combine, analyze, and synthesize two or more existing Studyes. The primary Studyes reviewed in this research are related to the impact of implementing the Problem Based Learning (PBL) model on students' mathematical critical thinking skills. The steps that need to be carried out in a meta-analysis study include establishing inclusion criteria for Studyes, conducting a literature search and selecting relevant Studyes, coding the Studyes, applying statistical analysis by calculating effect sizes, performing homogeneity tests to determine the appropriate analysis model, detecting and addressing potential biases, testing the null hypothesis, analyzing the characteristics of the involved Studyes, and interpreting the results of the analysis (Retnawati et al., 2018). The inclusion criteria for the primary Studyes used in this meta-analysis research include the following:

1. Educational Level : Studyes involving elementary school (SD), junior high school (SMP), senior high school (SMA), and higher education (universities).

2. Publication Year : Articles published between 2016-2019 and 2020-2023.

3. Research Location : Studyes conducted either on the island of Java or outside Java.

The teaching model applied is also one of the inclusion criteria. The control group in the primary Studyes received conventional teaching methods, while the experimental group was taught using the Problem Based Learning (PBL) model. The types of research conducted in the primary Studyes that meet the inclusion criteria are quasi-experimental Studyes with various research designs, such as: Randomized control group pretest-posttest design, randomized control group posttest-only design, nonequivalent group pretest-posttest design, nonequivalent group posttest-only design. The statistical data available in the primary Studyes include information on sample size, means, and standard deviations.

In conducting the literature search on the impact of the Problem Based Learning (PBL) model on students' critical thinking skills, researchers used the Sinta 1-5 database. Several keywords used in the journal literature search included "Pendidikan Matematika," "Mathematics Education," "Pembelajaran Matematika," and "Pengajaran Matematika." Additionally, keywords used to search for articles included "Problem Based Learning," "pembelajaran berbasis masalah," and "berpikir kritis matematis." This literature search resulted in 73 journal articles published between 2013 and 2023. Researchers then screened these 73 articles based on the previously established inclusion criteria. Out of these, 13 articles met the inclusion criteria and were included in the meta-analysis framework for this research.

Next, the researchers conducted the study coding stage, which involved applying a research instrument in the form of a coding protocol. This protocol consisted of a coding form that could be either paper-based or computerized. Additionally, a manual coding method was used, including detailed guidelines on how to code each item according to the data found in the original Studyes being analyzed (Wilson, 2009). After the coding process was completed, the authors calculated the effect size. Since the researchers aimed to measure the difference between two independent groups—namely, the experimental group that received the PBL model and the control group that received conventional teaching—and because the primary Studyes had small samples and sample standard deviations, the effect size used in this research is based on the standardized mean difference, specifically Hedges's g (Fritz et al., 2012). In this meta-analysis study, the interpretation of the effect size will use the following classification: (Cohen et al., 2007)

Table 1. Effect size Interpretation

ES	Interpretation ES
$0 \leq ES \leq 0{,}20$	Weak
$0{,}20 < ES \leq 0{,}50$	Simple
$0{,}50 < ES \leq 1{,}00$	Moderate
$ES > 1{,}00$	Strong

After calculating the effect size, the next step is to conduct a homogeneity test to determine the analysis model to be applied. This homogeneity test is conducted by referring to the p-value in the Q-statistic, consistent with the method applied in previous research (Retnawati et al., 2018). If the p-value is less than 0.05, it indicates that the distribution of effect sizes in the primary Studyes used in the meta-analysis is heterogeneous, and thus, the analysis model used is the random-effects model. However, if the p-value is greater than 0.05, it indicates that the distribution of effect sizes in the primary Studyes is homogeneous, and in this case, the fixed-effects model is used (Retnawati et al., 2018). Next, to ensure that the Studyes used in this meta-analysis represent all Studyes addressing the same research question and to avoid the claim that only Studyes with significant results are published and used in this meta-analysis, the authors need to detect and address publication bias (Valentine et al., 2017). Several methods can be used to detect and address publication bias, including funnel plot and Fail-Safe N (FSN) Rosenthal. The initial step in detecting publication bias is using the funnel plot. If the distribution of effect sizes in Studyes appears to be asymmetric or not symmetrical, Fail-Safe N (FSN) Rosenthal is used to help evaluate whether there is potential publication bias or not (Suparman et al., 2021). If there is no publication bias detected, the authors can proceed with the analysis process. Using the predetermined analysis model, the authors can conduct the null hypothesis test. If the p-value is less than 0.05, the null hypothesis is accepted, indicating that the implementation of Problem-Based Learning has a significant effect on students' mathematical critical thinking skills compared to Conventional Learning. If the analysis model used is the random-effects model, indicating variation in study characteristics, the authors can analyze the characteristics of the Studyes and then interpret the analysis results (Borenstein et al., 2010).

After calculating the effect size, the next step is to conduct a homogeneity test to determine the analysis model to be applied. This

3. Result and Discussion

The aim of this research is to obtain information about the combined effect size of implementing the PBL model on students' mathematical critical thinking abilities. Through this study, it is hoped to obtain results that explain the influence of implementing the PBL model on students' mathematical critical thinking abilities. Below is the list of selected Studyes that will be used in this research:

Table 2. The selected list of Studyes used in the research

Study code	Title	Journal
Study 1	Pengaruh Model Pembelajaran Problem Based Learning (Pbl) Terhadap Kemampuan Berpikir Kritis Matematis Siswa Pada Materi Sistem Persamaan Linear Dua Variabel (https://jurnal.ulb.ac.id/index.php/sigma/article/view/1943/1791)	Jurnal Pembelajaran dan Matematika Sigma (JPMS)
Study 2	Pengaruh Model Pembelajaran Problem Based Learning Terhadap Peningkatan Kemampuan Berpikir Kritis Matematis Siswa Smp Kelas IX (https://e-jurnal.lppmunsera.org/index.php/gauss/article/view/3129/1689)	GAUSS: Jurnal Pendidikan Matematika
Study 3	Students' mathematical critical thinking ability in problem-based learning viewed based on learning style (https://e-journal.hamzanwadi.ac.id/index.php/jel/article/view/4536/pdf)	Jurnal Elemen
Study 4	Pengaruh Model Problem Based Learning Terhadap Kemampuan Berpikir Kritis Matematis Siswa Kelas VIII SMP (https://ppjp.ulm.ac.id/journal/index.php/edumat/article/view/7078)	EDU-MAT: Jurnal Pendidikan Matematika
Study 5	Pengaruh Model Problem Based Learning Terhadap Kemampuan Berpikir Kritis Matematis Peserta Didik Kelas VIII SMP Negeri 2 Kendari (http://ojs.uho.ac.id/index.php/JPPM/article/view/9278)	Jurnal Penelitian Pendidikan Matematika
Study 6	A Comparative Study on Critical Thinking of Mathematical Problem Solving Using Problem Based Learning and Direct Intruction (https://www.atlantis-press.com/proceedings/access-19/125943898)	Advances in Social Science, Education and Humanities Research
Study 7	The Effect of a Problem Centered Learning on Student's Mathematical Critical Thinking (https://journals.ums.ac.id/index.php/jramathedu/article/view/8386/4756)	Journal of Research and Advances in Mathematics Education
Study 8	Pengaruh Model Pembelajaran PBL Berbantu Question Card terhadap Kemampuan Berpikir Kritis Siswa SMP (https://online-journal.unja.ac.id/edumatica/article/view/7683)	Edumatica - Jurnal Pendidikan Matematika
Study 9	Penerapan Model Pembelajaran Berbasis Masalah untuk Meningkatkan Kemampuan Berpikir Kritis Matematis dan Self Confidence Siswa (http://jurnal.fkip.unila.ac.id/index.php/MTK/article/view/16331)	Jurnal Pendidikan Matematika Unila
Study 10	Problem Based Learning dengan Strategi Konflik Kognitif Meningkatkan Kemampuan Berpikir Kritis Matematis (https://www.syekhnurjati.ac.id/jurnal/index.php/eduma/article/view/2887/1622)	EduMa
Study 11	Pengaruh Model Problem Based Learning Terhadap Berpikir Kritis Dan Hasil Belajar Elastisitas Siswa Kelas XI SMA Negeri 7 Banda Aceh (https://media.neliti.com/media/publications/122494-ID-pengaruh-model-problem-based-learning-te.pdf)	Jurnal Pendidikan Sains Indonesia
Study 12	Pengaruh Pengembangan Metode Problem Based Learning (PBL) terhadap Kemampuan Berfikir Kritis pada Mata Pelajaran IPA Kelas IV SD 1 Mardiatul Islamiyah (https://journal.universitaspahlawan.ac.id/index.php/jpdk/article/view/12925/9833)	Jurnal Pendidikan dan Konseling
Study 13	Pengaruh Model Problem Based Learning Terhadap Kemampuan Berpikir Kritis Matematis Siswa Dalam Memecahkan Masalah Matematika (https://ejournal.mandalanursa.org/index.php/JIME/article/viewFile/3217/2528)	Jurnal Ilmiah Mandala Education (JIME)

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

Table 3. The Hedges's g Value for Each Study

Lists of Studyes	Writer/Publication Year	Effect Size	Effect Size Interpretation	SE	Confidence Interval	
					Lower Bound	Higher Bound
Study 1	(Nufus et al., 2021)	1,1535	simple	0,3612	0,4457	1,8614
Study 2	(Sitompul, 2021)	4,2424	strong	0,5504	3,1635	5,3212
Study 3	(Susilo, 2022)	0,1978	lemah	0,2679	-0,2374	0,7229
Study 4	(Prihono & Khasanah, 2020)	0,532	moderate	0,2545	0,0332	1,0308
Study 5	(Steven et al., 2019)	0,4503	simple	0,2475	-0,0349	0,9354
Study 6	(Umar et al., 2020)	1,7684	simple	0,2751	1,2293	2,3076
Study 7	(Apriliana et al., 2019)	0,7164	moderate	0,2468	0,2327	1,2
Study 8	(Ratnawati et al., 2020)	0,31	simple	0,2371	-0,1548	0,7748
Study 9	(Marinda et al., 2018)	1,4314	strong	0,2953	0,8527	2,0102
Study 10	(Heryandi, 2018)	0,7627	moderate	0,2933	0,1879	1,3375
Study 11	(Rahayu et al., 2016)	2,2384	strong	0,331	1,5898	2,8871
Study 12	(Wahyuni et al., 2022)	0,7289	moderate	0,4225	-0,0992	1,5571
Study 13	(Kusumawardani et al., 2022)	0,5105	moderate	0,2541	0,0124	1,0086

Based on Table 3, there is variation in effect sizes across studies, with the range of effect sizes between 0.1978 and 4.24. Through interpretation of effect sizes based on Cohen's classification, it is noted that there are 3 studies with strong effect sizes, indicating that the implementation of the PBL model in these three studies has a strong influence on students' mathematical critical thinking abilities. Additionally, there are 5 studies with moderate effect sizes, indicating that the implementation of the PBL model in these five studies has a moderate influence on students' mathematical critical thinking abilities. Furthermore, there are also 3 studies with small effect sizes, indicating that the implementation of the PBL model in these three studies has a modest influence on students' mathematical critical thinking abilities. Lastly, there is 1 study with a weak effect size, indicating that the implementation of the PBL model in that study has a weak influence on students' mathematical critical thinking abilities. Homogeneity tests are conducted to select the estimation model to be used in calculating the combined effect size of all primary studies. To perform the homogeneity test, information presented in Table 4 is needed.

Table 4. Heterogeneity of Effect Size Distribution

Chi-Square	Df	P-Value	I-Square	σ^2
86,48	12	0,00	86	0,8537

Based on the information in Table 4, it can be observed that the p-value is < 0.05, indicating that the distribution of effect sizes in the primary studies used in the meta-analysis is heterogeneous. Therefore, the estimation model used to calculate the combined effect size is the random-effects model. To detect publication bias, the Fail-Safe N (FSN) is utilized, resulting in an FSN value of 376 from the 13 studies used in this research. Using the formula:

$\frac{376}{(5(k)+10),}$, where k is the number of observed studies, the value obtained is $\frac{376}{(5(13)+10)} = \frac{376}{75} = \mathbf{5.0133} > \mathbf{1.}$

Based on this research, it can be concluded that the studies used in this meta-analysis have a sufficient tolerance level for publication bias (Tamur et al., 2020). Furthermore, Table 5 presents the results of the meta-analysis from the primary studies using the fixed-effects model and the random-effects model.

Table 5. Results of Meta-Analysis Based on Estimation Models

Model	n	Effect Size and 95% Confidence Interval	Test of null (2-Tail)	Effect Size and 95%

				Confidence Interval			
		Effect Size	SE	Lower Bound	Highger Bound	Z-Value	P-Value
Fixed model effects	13	0,8819	0,1566	0,7253	1,0385	11,04	0,0001
Random effects model	13	1,1013	0,6232	0,478	1,7245	3,85	0,0023

Based on the homogeneity test analysis on the primary studies, it was found that the distribution of effect sizes showed significant heterogeneity. Therefore, in conducting the analysis, the random-effects model was used to combine findings from different studies. The random-effects model takes into account the variation among the studies included in the meta-analysis, acknowledging differences in characteristics and contexts among these studies. By using the random-effects model, more accurate estimates of the combined effect size can be obtained and can be broadly interpreted in a wider population. In Table 5, under the random effects model row, there is a p-value in the Z-test of 3.85. With a p-value < 0.05, it can be concluded that overall, the use of the PBL model has a more significant impact on students' mathematical critical thinking abilities compared to the conventional model. The results of the meta-analysis show that the combined effect size is 1.1013, which according to Cohen's classification falls into the category of a strong effect size. Thus, the conclusion is that overall, the implementation of the PBL model has a strong influence on students' mathematical reasoning abilities. Furthermore, a combined effect size of 1.1013 means that the mean ability increased by 86% compared to the control group.

Due to the heterogeneity in the distribution of primary study effects, it is important to conduct an analysis of study characteristics to identify factors contributing to heterogeneity in students' mathematical critical thinking abilities.

Table 6. Results of Meta-Analysis for Each Study Characteristic

Study Characteristics	**Kategori**	**n**	**Hedges'sg (effect size)**	**Test of null (2-Tail)**	**95% CI**	
				P-Value	Lower Bound	Higher Bound
Education Level	SD	2	1,3	0,04	-5,28	7,87
	SMP	8	1,13	0,00	0,13	2,13
	SMA	2	1,36	0,00	-9,61	12,33
	PT	1	0,2	0,00	0,48	1,72
Publication Year	2016-2019	6	1,13	0,00	0,9	1,35
	2020-2023	7	0,64	0,00	0,42	0,86
Place	Jawa	5	0,49	0,48	0,26	0,72
	Non-Jawa	8	1,24	0,00	1,03	1,46

Based on the data in Table 6, it can be concluded that the level of education has a significant impact on students' critical thinking abilities. This can be seen from the effect sizes present in each educational level. The analysis results show that the highest effect size is in the Senior High School (SMA) level at 1.36 and the lowest is in the Higher Education (PT) level at 0.2. From the data presented in Table 6, it is evident that the upper and lower bounds at the SMA level indicate a larger effect than other levels. All effect size values across educational levels overlap, indicating that the effect of PBL on critical thinking abilities applies uniformly across all educational levels and is not influenced by the level of education.

Furthermore, the data in Table 6 also include characteristics based on the publication years of the studies. In Table 6, it can be seen that the research year also influences critical thinking abilities with PBL learning. This research indicates that each analyzed year has a significant impact, with a moderate level of effect in the years 2020-2023 and a high level in the years 2016-2019. Although the effect sizes within each year range differ, there is an overlap in the upper and lower bounds of both year ranges, indicating no significant difference in the effect of PBL on students' mathematical critical thinking abilities between the 2016-2019 and 2020-2023 periods. Therefore, it can be concluded that there is no significant difference in the impact of PBL learning on students' mathematical critical thinking abilities based on the research year.

In Table 6, there are study characteristics based on the geographical scope of the research. From the table, it can be seen that critical thinking abilities in PBL learning are also influenced by the research region. The effect size in regions outside Java, which is 1.24, is larger than the effect size in studies

conducted in the Java region, which is 0.49. There is no overlap in the upper and lower bounds of the two geographical criteria. From the data, it is known that in regions outside Java, the influence of PBL on mathematical critical thinking abilities is higher than in the Java region.

4. Equations

The meta-analysis results from 12 studies investigating the impact of learning on students' mathematical conceptual understanding abilities show that the combined effect size from the primary studies is 1.1013, placing it in the high effect size category according to Cohen's classification. Therefore, it can be concluded that overall, the implementation of Problem-Based Learning (PBL) does not demonstrate a high and significant influence on students' critical thinking abilities compared to the application of conventional learning models and other teaching methods.

Furthermore, an analysis of several study characteristics indicates that the influence of Problem-Based Learning (PBL) on improving students' mathematical critical thinking abilities is not significantly influenced by educational level or research year but is influenced by the research location. These findings provide important information for teachers in selecting and implementing the PBL teaching model to enhance students' mathematical critical thinking abilities according to their educational level. However, the authors also recommend that this study be further examined to gain a deeper understanding.

References

Apriliana, L. P., Handayani, I., & Awalludin, S. A. (2019). The Effect of a Problem Centered Learning on Student's Mathematical Critical Thinking. JRAMathEdu (Journal of Research and Advances in Mathematics Education), 4(2), 124–133. https://doi.org/10.23917/jramathedu.v4i2.8386

Heryandi. (2018). Problem Based Learning dengan Strategi Konflik Kognitif Meningkatkan Kemampuan Berpikir Kritis Matematis Yandi Heryandi. EduMa: Mathematics Education Learning and Teaching, 7(1), 93–108.

Kusumawardani, N. N., Rusijono, R., & Dewi, U. (2022). Pengaruh Model Problem Based Learning Terhadap Kemampuan Berpikir Kritis Matematis Siswa Dalam Memecahkan Masalah Matematika. Jurnal Ilmiah Mandala Education, 8(2), 1416–1427. https://doi.org/10.58258/jime.v8i2.3217

Marinda, H., Noer, S. H., & Asnawati, R. (2018). Penerapan Model Pembelajaran Berbasis Masalah untuk Meningkatkan Kemampuan Bepikir Kritis Matematis dan Self Confidence siswa. Jurnal Pendidikan Matematika Unila, 6(6), 559–570.

Nufus, H., Herizal, & Dewi Sahputri, L. (2021). Pengaruh Model Pembelajaran Problem Based Learning (Pbl) Terhadap Kemampuan Berpikir Kritis Matematis Siswa Pada Materi Sistem Persamaan Linear Dua Variabel the Effect of Model Problem Based Learning (Pbl) on Student'S Mathematical Critical Thinking Skill. 7(1), 2460–2593.

Prihono, E. W., & Khasanah, F. (2020). Pengaruh Model Problem Based Learning Terhadap Kemampuan Berpikir Kritis Matematis Siswa Kelas Viii Smp. EDU-MAT: Jurnal Pendidikan Matematika, 8(1), 74–87. https://doi.org/10.20527/edumat.v8i1.7078

Rahayu, Ismail, S., & Hasan, M. (2016). Pengaruh Model Problem Based Learnig Terhadap Berpikir Kritis dan Hasil Belajar Siswa Kelas XI SMA Negeri 7 Banda Aceh. Jurnal Pendidikan Sains Indonesia, 04(02), 105–116.

Ratnawati, D., Handayani, I., & Hadi, W. (2020). Pengaruh Model Pembelajaran PBL Berbantu Question Card terhadap Kemampuan Berpikir Kritis Matematis Siswa SMP The Influence of PBL Model Assisted by Question Card toward Mathematic Critical Thinking in JHS. Edumatica, Jurnal Pendidikan Matematika, 10(1), 44–51.

Sitompul, N. N. S. (2021). Pengaruh Model Pembelajaran Problem Based Learning terhadap Peningkatan Kemampuan Berpikir Kritis Matematis Siswa SMP Kelas IX. GAUSS: Jurnal Pendidikan Matematika, 4(1), 45–54. https://doi.org/10.30656/gauss.v4i1.3129

Steven, D., La Ndia, L. N., & La Arapu, L. A. (2019). Pengaruh Model Problem Based Learning Terhadap Kemampuan Berpikir Kritis Matematis Peserta Didik Kelas Viii Smp Negeri 2 Kendari. Jurnal Penelitian Pendidikan Matematika, 7(3), 15. https://doi.org/10.36709/jppm.v7i3.9278

Susilo, B. E. (2022). Students' mathematical critical thinking ability in problem-based learning viewed based on learning style. Jurnal Elemen, 8(1), 187–200. https://doi.org/10.29408/jel.v8i1.4536

Umar, U., Kaharuddin, A., Fauzi, A., Widodo, A., Radiusman, R., & Erfan, M. (2020). A Comparative Study on Critical Thinking of Mathematical Problem Solving Using Problem Based Learning and Direct Intruction. 465(Access 2019), 314–316. https://doi.org/10.2991/assehr.k.200827.079

Wahyuni, A. P., Purba, A. R. A. b, Hasibuan, M. A., & Harahap, R. C. (2022). Pengaruh Pengembangan Metode Problem Based Learning (PBL) terhadap Kemampuan Berfikir Kritis pada Mata Pelajaran IPA Kelas IV SD 1 Mardiatul Islamiyah. Jurnal Pendidikan Dan Konseling, 4, 1349–1358.

Yew, E. H. J., & Goh, K. (2016). Problem-Based Learning: An Overview of its Process and Impact on Learning. Health Professions Education, 2(2), 75–79. https://doi.org/https://doi.org/10.1016/j.hpe.2016.01.004