



# Meta-Analysis: The Effectiveness of Problem-Based Learning in Improving Elementary School Students' Critical Thinking Skills in Science Learning

Anak Agung Sagung Krisna Darmawati<sup>1\*</sup>, I Nyoman Tika<sup>1</sup>, Putu Artawan<sup>1</sup>, I Wayan Redhana<sup>1</sup>

<sup>1</sup> Science Education Study Program, Postgraduate Program, Universitas Pendidikan Ganesha, Singaraja, Indonesia.

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Corresponding Author:

Anak Agung Sagung Krisna Darmawati  
[sagungkrisnadarmawati@gmail.com](mailto:sagungkrisnadarmawati@gmail.com)

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**Abstract:** The implementation of science learning in schools must be designed to provide a means for students to deepen their understanding of themselves and the natural world or their surroundings. However, in practice, several obstacles or difficulties are encountered, including the lack of facilities and teachers' skills. This research aims to analyze the effectiveness of the implementation of Problem-Based Learning (PBL) in improving the critical thinking skills of elementary school students in science education through a meta-analysis method. This method was conducted on nine journals resulting from quasi-experimental research published between 2021 and 2025. Problem-Based Learning (PBL) has been extensively studied as a learning model believed to be effective in enhancing students' critical thinking skills. The journals were selected based on specific inclusion criteria and analyzed using the RevMan 5.4.1 software to measure effect size. The analysis results show that the implementation of PBL significantly improves students' critical thinking skills, indicated by an overall effect value ( $P < 0.00001$ ). There is variation in results among the analyzed journals, with effect sizes generally ranging from high to very high. These findings support that PBL can be an effective alternative for teachers in developing students' critical thinking skills, especially in science subjects which are abstract in nature and require problem-solving. The application of PBL is also recommended to be developed at higher education levels.

**Keywords:** Broiler; Critical thinking; Meta analysis; Problem based learning; Science

## Introduction

21st-century skills, also known as 21st-Century Skill Characteristics, are skills that must be developed in education, especially in Indonesia. These skills are known as the 4Cs: critical thinking, communication, collaboration, and creativity (Thornhill-Miller et al., 2023; Azmi et al., 2024). Critical thinking is a crucial skill for anyone in life. Everyone needs critical thinking skills to solve every problem they face in life. Critical thinking

is one of the skills needed in the 21st century (Van Laar et al., 2020; Kocak et al., 2021). Critical thinking involves rational and mature problem-solving skills in the learning process. Teaching and honing students' critical thinking skills in the classroom is crucial, as critical thinking requires concentration, strong analytical skills, sound problem-solving, and more mature thought processing (Simonovic et al., 2023; Rivas et al., 2023). One subject that can improve critical thinking skills is Natural Sciences (IPA). This is because it studies scientific phenomena in everyday life, enabling students

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to behave and act appropriately. According to (Amaliyah et al., 2024; Kelana et al., 2022), science is knowledge, a process of inquiry, and a scientific attitude, reflected in the essence of science. The material contained in science provides students with experiences with knowledge, ideas, and concepts about the environment and natural phenomena through a series of scientific processes (Pulungan et al., 2021).

The application of PBL in lessons also encourages students to actively participate in learning activities, thereby creating a relevant and enjoyable learning environment and atmosphere (Capatina et al., 2024; Dai et al., 2023). Several studies have been conducted on the effect of PBL on improving students' critical thinking skills. Previous studies have shown that PBL has a positive and significant impact on improving students' critical thinking skills (Anggraini et al., 2022; Nurmasari, 2023; Saila, 2023). To determine the impact and effectiveness of PBL implementation in science learning, further study and analysis are needed (Aisyah & Usdiyana, 2022; Goyal et al., 2022; Abas et al., 2024). This analysis was conducted to determine the accuracy or validity of the results or conclusions from the application of PBL in learning. One study or analysis that can be conducted is a meta-analysis. The meta-analysis method is a research that uses existing studies systematically and quantitatively to obtain accurate conclusions.

Meta-analysis is conducted because the reality is that no research is free from errors in research, even though researchers have attempted to minimize errors or errors that occur in the study (Paul & Barari, 2022; Gusenbauer & Gauster, 2025; Allen, 2020). Based on this, this study was conducted to test the effectiveness (effect size) of the application of the Problem Based Learning model in improving students' critical thinking skills in science learning.

**Method**

This research employed a meta-analysis method, which examines journals from various sources and then analyzes the results according to the topic being analyzed. This study examined the effectiveness of the Problem-Based Learning (PBL) model in improving elementary school students' critical thinking skills in science. Data collection was conducted using the Publish or Perish application, using the Crossef database, and using the keywords "Problem Based Learning" or "IPA" or "critical thinking" for the 2021-2025 period. The journal screening process used the PRISMA method with the following inclusion criteria: journals discussing the application of PBL in science learning; journals measuring critical thinking variables; research

conducted at the elementary school level; and research using a quasi-experimental method with data on the mean, standard deviation, and sample population. Based on the search results, 500 journals matched the keywords and the PRISMA screening results using the inclusion criteria used, resulting in nine journals for analysis. The selection stage using the PRISMA method can be seen in Figure 1.

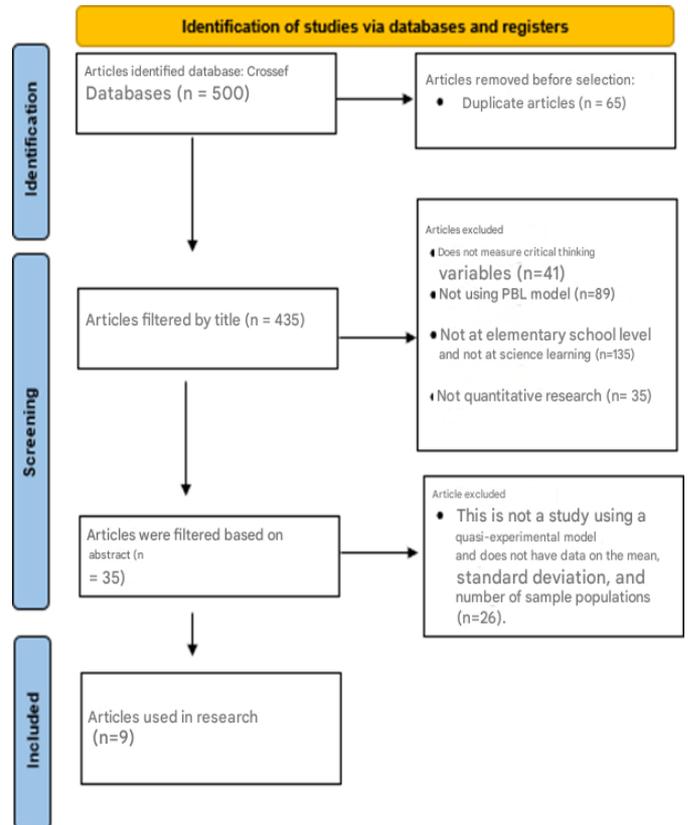


Figure 1. PRISMA diagram of the journal screening process

The screening results were then analyzed for effect size values using RevMan 5.4.1 software, using the mean, standard deviation, and sample size from each journal. The effect size criteria can be seen in Table 1.

Table 1. Effect Size Criteria

Effect Size	Category
$ES \leq 0.15$	Negligible
$0.15 < ES < 0.40$	Low
$0.40 < ES < 0.75$	Medium
$0.75 < ES < 1.10$	High
$1.10 < ES < 1.45$	Very High

**Result and Discussion**

The results of the screening process using the PRISMA model inclusion criteria resulted in nine journals for further analysis. The journal data for analysis is shown in Table 2.

**Table 2.** Journal Screening Results

Journal Code	Title	Author (Year)	Level	Class	Method
PB1	Model Problem Based Learning Berbantuan Audio Visual Meningkatkan Keterampilan Berpikir Kritis dan Hasil Belajar IPA Siswa Kelas IV SD	(Chandan et al., 2024)	SD	IV	Quasi Experiment
PB2	Pengaruh Model Pembelajaran Problem Based Learning terhadap Kemampuan Berpikir Kritis pada Pembelajaran IPA Siswa Kelas IV SDN 07 Woja Kabupaten Dompu	(Amalia et al., 2024)	SD	IV	Quasi Experiment
PB3	Pengaruh Model Pembelajaran Problem Based Learning (Pbl) Terhadap Kemampuan Berpikir Kritis IPA Siswa Kelas V SDN Cogreg I Kabupaten Tangerang	(Anggraini et al., 2022)	SD	V	Quasi Experiment
PB4	Pengaruh Model Pembelajaran Problem Based Learning (PBL) terhadap Kemampuan Berpikir Kritis Siswa Pada Pembelajaran IPA Kelas IV SDN Beleka Tahun 2021/2022	(Mariskhantari et al., 2022)	SD	IV	Quasi Experiment
PB5	Pengaruh Model Problem Based Learning Berbantuan Mind Mapping Terhadap Kemampuan Berpikir Kritis Dan Kreativitas Siswa Pada Mata Pelajaran IPA Kelas V Gugus IV Kecamatan Abang Kabupaten Karangasem Tahun Pelajaran 2022/2023	(Ni Wayan Devi Krisnayanti et al., 2023)	SD	V	Quasi Experiment
PB6	Pengaruh Model Problem Based Learning Terhadap Kemampuan Berpikir Kritis Dan Hasil Belajar Ipa Pada Siswa Sekolah Dasar	(Rambe et al., 2023)	SD	V	Quasi Experiment
PB7	Efektivitas Model Problem Based Larning dan Problem Solving untuk Meningkatkan Kemampuan Berpikir Kritis Siswa dalam Pembelajaran IPAS	(Susanto & Airlanda, 2023)	SD	IV	Quasi Experiment
PB8	Pengaruh Model Problem Based Learning dan Motivasi Belajar Terhadap Kemampuan Berpikir Kritis Siswa Pada Mata Pelajaran IPA Kelas V Sekolah Dasar	(Triandika et al., 2023)	SD	V	Quasi Experiment
PB9	Efektivitas Model Problem-Based Learning Berbantu Lkpd Etnosains Ponorogo Terhadap Kemampuan Berpikir Kritis IPA SD	(Wahyuningtyas et al., 2023)	SD	V	Quasi Experiment

Based on all of these journals, the analysis data was then grouped by unit, as shown in Table 3.

**Table 3.** Journal Grouping Data

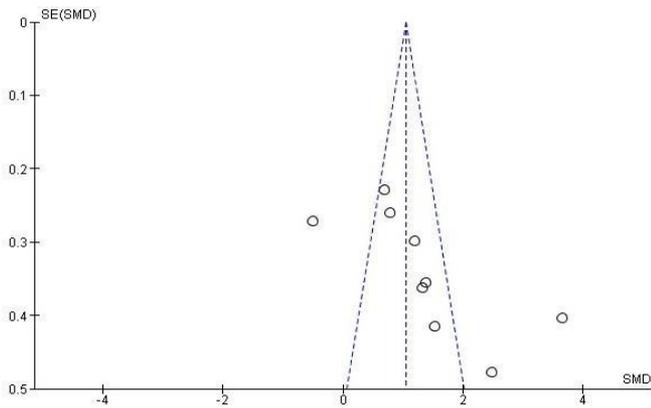
Analysis Group	Unit of Analysis	Number of Analysis Units
Education Level	Elementary School Grade IV	4
	Elementary School Grade V	5
	Critical Thinking Skills	9
Dependent Variable	Problem-Based Learning	9

Based on Table 3, there are 9 journals to be analyzed, consisting of 4 journals for grade IV elementary school and 5 journals for grade V elementary school. All journals use the Problem-Based Learning learning model with critical thinking skills as the dependent variable. After all journals were grouped, the next step was the statistical data analysis process, which can be seen in Table 4.

The data in Table 4 were then analyzed using the meta-analysis application RevMan 5.4.1. The first analysis performed was a publication bias test using a funnel plot and the fail-safe N (FSN) test. The results of the analysis can be seen in Figure 2.

**Table 4.** Statistical Data Extraction Results

Journal code	Statistical Data					
	Experimental Group			Control Group		
	Mean	SD	N	Mean	SD	N
PB1	83.82	8.16	34	55.32	7.25	34
PB2	83.50	8.29	20	71.75	8.47	20
PB3	79.37	4.88	32	73.43	9.47	32
PB4	78.54	11.42	41	70.38	12.11	40
PB5	84.23	5.19	17	63.12	10.65	16
PB6	79.96	12.03	27	63.44	14.91	27
PB7	87.50	7.99	28	91.07	5.67	28
PB8	89.53	5.42	19	82.37	5.23	19
PB9	83.66	9.44	15	66.56	12.17	16



**Figure 2.** Funnel plot bias test

Figure 2 shows the bias test, or the uneven or asymmetric distribution of effect sizes for each journal on the left and right sides, making them difficult to interpret. The next step is to test the effect sizes for each journal. The test results can be seen in Table 5.

Based on Table 5, it can be seen that each journal has a mean value, standard deviation, and sample size for both the experimental and control groups. The data were then calculated and analyzed using the effect size formula in RevMan 5.4.1, which then produced the Std. Mean Difference, a standardized effect size. The results in Table 5 indicate that each journal has a varying effect size on PBL learning on students' critical thinking skills. Very high effect sizes are shown in six journals: journals coded PB1, PB2, PB5, PB6, PB8, and PB9. High effect sizes are indicated by journal coded PB3, moderate effect sizes are indicated by one journal coded PB4, and negligible effect sizes are shown in journal PB7. In journal PB7, the effect size is very low, even negative, due to the lack of impact of PBL implementation on students' critical thinking skills as reported by the journal's researchers (Mutiarra et al., 2024; Chen et al., 2021; Yu & Zin, 2023). The meta-analysis also yielded heterogeneity, as can be seen in Table 6.

**Table 5.** Effect Size Test Results

Journal code	Statistical Data						Std. Mean Difference (Effect Size)	Information
	Experimental Group			Control Group				
	Mean	SD	N	Mean	SD	N		
PB1	83.82	8.16	34	55.32	7.25	34	3.65	Very high
PB2	83.50	8.29	20	71.75	8.47	20	1.37	High
PB3	79.37	4.88	32	73.43	9.47	32	0.78	Moderate
PB4	78.54	11.42	41	70.38	12.11	40	0.69	Very high
PB5	84.23	5.19	17	63.12	10.65	16	2.48	Negligible
PB6	79.96	12.03	27	63.44	14.91	27	1.20	Very high
PB7	87.50	7.99	28	91.07	5.67	28	-0.51	Very high
PB8	89.53	5.42	19	82.37	5.23	19	1.32	Very high
PB9	83.66	9.44	15	66.56	12.17	15	1.52	Very high

**Table 6.** Meta-Analysis Also Yielded Heterogeneity

Study of subgroup	Experimental			Control			Weight (%)	Std. Mean Difference IV, Fixed, 95 % CI
	Mean	Sd	Total	Mean	Sd	Total		
Chandan et al. (2024)	8.38	826	34	5.53	725	34	6.80	3.65(2.86, 4.44)
Amalia et al. (2022)	8/35	829	20	7.17	847	20	8.70	1.37(0.68, 2.07)
Anggraini et al. (2022)	7.93	488	32	7.34	947	32	16.30	0.78(0.27, 1.29)
Mariskantari et al. (2022)	7.85	1.14	41	7.03	1.21	40	21	0.69(0.24, 1.14)
Ni Waya Devi Krisnayanti et al. (2023)	8.42	519	17	6.31	1.06	16	4.90	2.48(1.55, 3.42)

Study of subgroup	Experimental			Control			Weight (%)	Std. Mean Difference IV, Fixed, 95 % CI
	Mean	Sd	Total	Mean	Sd	Total		
Rambe et al. (2023)	7.99	1.20	27	6.34	1.49	27	12.50	1.20(0.62, 1.78)
Susanto & airlanda (2023)	8.75	7999	28	9.10	567	28	14.90	-0.51(-1.04, 0.02)
Triandika et al. (2023)	8.95	542	19	8.23	523	19	8.40	1.32(0.61, 2.02)
Wahyuningtyas et al. (2023)	8.36	944	15	6.66	1.21	16	6.40	1.52(0.71,2.34)
Total 95 % CI			233			232	100	1.04(0.84,1.25)

Heterogeneity, Chi\*=89.94, df=8(P<0.00001); P=91%  
 Test for overall effect Z=9.92(P<0.00001)

Figure 3 shows the results of the heterogeneity test. The heterogeneity test aims to examine or determine data variation across all studies used in the meta-analysis. The results of the heterogeneity test can be seen from the P value (0.05) or the I2 value (>50%). The P value in the figure shows a value of (P <0.00001), indicating that the journals in this meta-analysis exhibit high heterogeneity or significant variation. This confirms the results of the funnel plot in Figure 2. These results require additional analysis to identify the mediating variables causing the high heterogeneity. The overall effect results in Figure 3 serve to determine the effectiveness of the PBL model in improving students' critical thinking skills. The overall effect results in Figure 3 show a value of (P <0.00001), indicating that PBL has a significant effect on improving students' critical thinking skills, as the P value is <0.05. This result can also be seen in the forest plot illustration in Figure 3:

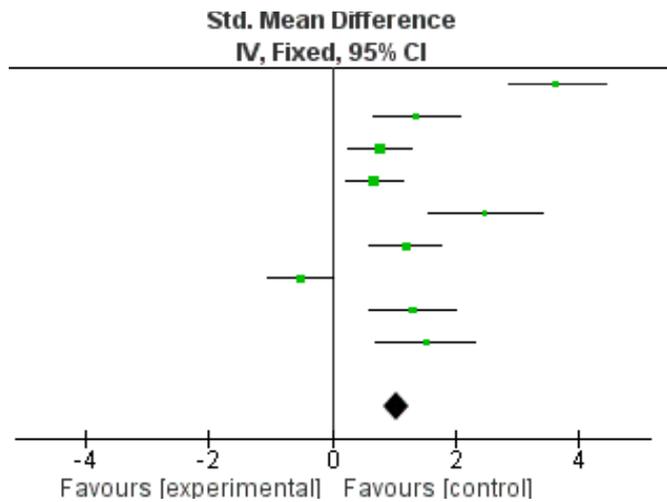


Figure 3. Effect Size of each journal illustrated in a forest plot

According to Figure 3, almost all journals fall to the right of the 0 (zero) value, indicating that almost all journals have a positive effect on improving students' critical thinking skills through the implementation of the PBL model. The meta-analysis results align with previous research showing that the implementation of the Project-Based Learning (PBL) model can improve students' critical thinking skills (Tafakur et al., 2023; Zhang et al., 2024; Markula & Aksela, 2022). Research conducted by Wahdaniyah et al. (2023), Khoirulloh et al.

(2024), and Samadun et al., (2022), found that the implementation of PBL can improve students' critical thinking skills because in the PBL model, students are faced with problems that must be solved using scientific steps, which can improve students' critical thinking skills (Diani et al., 2020; Afikah et al., 2022; Adnyani & Suniasih, 2023).

The implementation of science learning in schools must be designed to provide a means for students to deepen their understanding of themselves and the natural world or their surroundings (Skalstad & Munkebye, 2022; Ribeiro et al., 2024; Zamiri & Esmaeili, 2024). However, in practice, several obstacles or difficulties are encountered, one of which is related to the teaching materials and skills of teachers (Dursun & Aykan, 2025; Sadeghi & Richards, 2021; Chistyakov et al., 2023). Some of the difficulties teachers face in teaching science include a lack of understanding of learning models or methods, learning media (Sarmi et al., 2019; Magaji et al., 2024; Kartini et al., 2022), and lesson plans that can connect abstract science material to more contextual material (Sumampan et al., 2022; Dewi & Agustika, 2022; Ardithayasa et al., 2022).

A learning model is a plan or pattern that teacher can use to design learning materials and guide classroom learning. One learning model that can be applied to science lessons is Problem-Based Learning (PBL) (Nur'ariyani et al., 2023; Sa'adah et al., 2023; Darling-Hammond et al., 2020). PBL is a learning model that involves students in solving problems using several stages of the scientific method, enabling students to acquire knowledge related to the topic at hand (Handayani & Alperi, 2021; Phungsuk et al., 2017; She et al., 2017). This is expected to encourage students to think critically to solve the problems they face.

## Conclusion

Based on research and analysis of 9 journals that have been conducted regarding the effectiveness of the application of Problem Based Learning in improving the critical thinking skills of elementary school students (SD), it can be concluded that the application of PBL has a significant effectiveness or influence in improving students' critical thinking skills. This can be seen from

the results of the Overall effect showing a value ( $P < 0.00001$ ). Through the results of this study, teachers are advised to use the Problem Based Learning model in the learning carried out, especially in abstract subjects such as science because students learn from scientific problems that occur so that they can improve their ability to solve problems that require critical thinking skills. In addition, this PBL model is also expected to be applied at higher levels of education, because the problems faced by students at higher levels will be increasingly complex which will stimulate an increase in critical thinking skills which are abilities that students must have in the 21st century.

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A.A.S.K.D. conducted the research; I.N.T., P.A., and I.W.R reviewed and edited the manuscript.

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#### Conflicts of Interest

The authors declare no conflict of interest.

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