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The Effect of Problem Based Learning Model on Critical Thinking Skills in Elementary School: A Meta Analysis Study

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ABSTRACT

Critical thinking was an essential skill that must be taught from elementary school to address the challenges of problem-solving in the development of science and technology. Critical thinking skills of the 21st century could be developed by applying the Problem Based Learning model. The article aimed to test the validation of the effect of the Problem Based Learning model on the critical thinking skills of elementary school students in Indonesia. The research method used quantitative meta-analysis method that was assisted by JASP 0.8.5 software. Research data used with eligibility criteria, including: (1) publications could be traced in Google Scholar, (2) publications are only indexed by SINTA, (3) publications must be related to the topic, (4) publication subjects must be at the elementary school level, (5) publications results from Indonesia, (6) publications include (r), (t) or (F) values, (7) publications must be published in the range of 2014 to 2022, (8) publications must have N ≥ 20. The results showed that in 25 research articles, there was a significant effect of applying the Problem Based Learning model on the critical thinking skills with a strong category. It contributed on problem-based learning model has a significant impact on the formation and development of critical thinking skills among elementary school students in Indonesia.

Keywords: *Critical Thinking Skill, Problem Based Learning, Students Critical Thinking*

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INTRODUCTION

21st century education should teach students to be lifelong learners with the ability to learn, adapt and master new skills continuously throughout life. 21st century education in primary schools refers to a learning approach that focuses on developing skills, understanding and values relevant to the demands of an ever-evolving and complex world in the 21st century (Mardhiyah et al., 2021). 21st century education in primary schools aims to create a generation that is ready to face future challenges with confidence, has relevant skills, and has a deep understanding of the world around them (Alifah & Sukartono, 2023; Astuti, 2021; Astutik & Hariyati, 2021).

21st century skills are qualities that are considered important for individuals to become competitive, innovative, and meaningful members of society (Fitria et al., 2023). 21st century education seeks to develop critical thinking, innovative, communicative, creative, and collaborative skills in students to be ready to face challenges and opportunities in a rapidly changing world (González-Salamanca et al., 2020; Işiklar & Öztürk, 2022). 21st century skills refer to the collection of skills and abilities considered essential to succeed and contribute effectively in the modern era (Martinez, 2022).

The emergence of demasnding 21st century skills, such as critical thinking, creativity, collaboration, and digital literacy, demands changes in learning approaches and curricula to enable students to develop these skills effectively (Lombardi et al., 2021). Education in primary schools should emphasize the development of 21st century skills, such as critical thinking, creativity, communication, collaboration, problem solving, digital skills, and social skills (Mashudi, 2021; Redhana, 2019). These skills are important to help students face future challenges and become competent global citizens. One of the important skills to face the challenges of 21st century life problems is critical thinking skills. According to Razak (2022) critical thinking skills are the ability to analyses, evaluate, synthesize information, and critically reflectively solve problems logically and rationally by considering the complex context of the modern world. Critical thinking involves the ability to connect information, recognize patterns, and make informed decisions.

Critical thinking skills for the 21st century have become very important in facing the challenges of a complex and fast-paced modern world (Syah et al., 2021). By focusing on developing critical thinking skills, individuals can become lifelong learners who can adapt to change and make smart and responsible decisions. According to Changwong (2018), educated critical thinkers can conduct a broader exploration of problems by considering from various perspectives. Critical thinking skills emphasize the ability to analyses deeply and thoroughly (Moosavi, 2020; Slameto, 2016). Critical thinking as an intellectual discipline process that actively and skilfully conceptualizes, applies, analyses, synthesizes, and/evaluates information collected from, or generated by observation, experience, reflection, reasoning, or communication as a guide in carrying out an action or belief in making a decision (Belecina & Ocampo, 2018; Sellars et al., 2018).

According to Ennis (2011) there are several basic indicators of critical thinking, namely focus, reason, inference, situation, clarity and overview. Focus is focusing the questions contained in the problem to make decisions about what is believed. Reason is knowing the reasons that support or reject the decisions made based on the facts contained in the problem. Inference is making a reasoned or convincing conclusion. Situation is understanding the situation and keeping the situation in mind to help clarify the question and know the meaning to support the decision taken. Clarity is explaining the meaning or terms used, and Overview is reviewing and thoroughly examining the decisions taken. Critical thinking is also referred to as metacognition or the process of thinking about thinking (Karahan et al., 2023). According to Reeder (1984) the critical thinking process involves a reflective attitude. Critical thinking skills are important because they enable students to deal effectively with social, scientific, and practical issues (Miterianifa et al., 2021; Thompson, 2011). The learning process by only transferring knowledge or information in one direction without any development in students is not able to make students a 21st century generation. With critical thinking

skills possessed by students, it encourages increasing the ability to solve problems effectively (Sundari et al., 2023).

Critical thinking skills as the main basis for developing problem solving skills (Tohani & Aulia, 2022; Wardani & Fiorintina, 2023). Critical thinking skills are one of the skills that students must have in order to be able to find steps to solve problems, and formulate several problem solutions (Hidayah et al., 2017; Septikasari & Frasandy, 2018). Critical thinking skills can be instilled in various disciplines or learning materials (Rahardhian, 2022; Setyowati et al., 2018). Teachers play an important role in supporting the improvement and formation of students' critical thinking skills through the application of various types of learning models that can encourage students to learn to actively seek and find problem solving through critical thinking activities. According to Ferkany & Godden (2023) that by improving critical thinking skills, a person can contribute to the improvement and intellectual cultivation of their critical thinking skills. Based on a survey conducted by Kay about expectations from industry reported that the skills needed as a strength to support the success of the world of work in the next five years, one of which is critical thinking (78%) (Dewi et al., 2022; Nafiah & Suyanto, 2014). The data shows the importance of developing thinking skills for children as a provision for life. According to Rahmasari (2021) children must be trained to think critically about every fact found from an early age. Careful in finding and initiating problem-solving solutions.

However, data indicates that the critical thinking skills of Indonesian students or even the critical thinking skills of Indonesia's young generation are at a low level, namely the easier spread of HOAX news through the use of digital media without any critical thinking skills in criticizing and analysing news or information, especially in problem solving (Basri et al., 2021; Siga et al., 2023; Stella et al., 2022). Based on the research results of the KIC research survey, there are 11.9% of the public who are still spreading hoax news in 2021 and have increased from the previous year, namely 2020 by 11.2% (Azis et al., 2022; Talalu et al., 2022). The data from the KIC survey is an indicator that almost 60% of Indonesians are exposed to HOAX when accessing the internet (PISA results) (Amaly & Armiah, 2021). Meanwhile, according to the Research and Development Agency of the Ministry of Home Affairs, it was found that 44% of hoaxes could not be detected by the Indonesian people (Delmana, 2023). These findings are supported by PISA 2012 data, which indicates that the critical thinking skills of Indonesian students are categorized as low, ranking 64th, with their ability to answer questions only at levels 1 and 2 (Berjamai & Davidi, 2020). This suggests that young Indonesians are not trained from elementary school to critically analyze contextual problems occurring in real life. This indicates the low level of evaluative skills, one of the key indicators of critical thinking skills. The weak ability to analyze and answer questions, as evidenced by PISA 2012 data, demonstrates the inadequate critical thinking skills in society, particularly among students, in addressing various social issues and real life problem solving. Critical thinking is a crucial characteristic for preparing the younger generation to face the challenges posed by technological and scientific advancements, which influence changes in various dynamic social issues (Alsaleh, 2020; Gökçearslan et al., 2019; Moustaghfir & Brigui, 2024). Critical thinking skills provide a fundamental foundation for shaping students into intelligent individuals capable of creating solutions to current and future life problems.

Critical thinking skills should be taught early, especially since children enter elementary school to prepare the younger generation to face the challenges of life (Southworth, 2022; Sukardjo et al., 2023). According to Manassero (2022), critical

thinking is an educational innovation that comprehensively teaches young generations 21st century skills. This indicates that critical thinking is a fundamental skill that must be developed in the educational process to address the challenges of the era of open knowledge and technology.Teachers as educators take part in preparing learning designs by combining various learning models that can encourage the increase and formation of students' critical thinking skills. One of them is by applying the Problem Based Learning model.

21st century problem-based learning is a learning approach that emphasizes solving real problems and complex situations in the context of the ever-evolving modern world (Indriani & Zakariyah, 2022; Wulandari, 2021). According to Boud (2012) in Problem Based Learning, students are given relevant and authentic problems or challenges to solve, and they take an active role in finding solutions by utilizing the knowledge and skills they have. According to Agustini (2020) the problems presented in problem-based learning are directly related to real life and have a clear relevance to the world around students. This provides high motivation for students because they see the importance of solving these problems in the context of their lives.

Problem-based learning plays a crucial role in enhancing the critical thinking skills of elementary school students. This model places students in real life situations that require problem solving, thereby encouraging them to analyze, evaluate, and develop effective solutions (Adeliana et al., 2021; Indrapangastuti1 et al., 2024; Yuan et al., 2008). In the context of elementary education, the problem-based learning model allows students to connect theory with practice, making learning more relevant and engaging.

One of the main reasons problem-based learning is effective in developing and shaping critical thinking skills is that it actively involves students in the learning process. Students do not just passively receive information but also actively participate in the exploration and discovery of knowledge (Arifin, 2020; Dayu et al., 2022; Jamilah et al., 2023; Masruro et al., 2021; Shandy et al., 2024). This approach helps students develop critical thinking skills, such as the ability to identify problems, ask pertinent questions, gather and analyze data, and evaluate alternative solutions.

The use of problem-based learning for critical thinking must follow the steps in this model correctly. Problem based learning has several steps that can be implemented, namely: (1) problem or challenge identification, (2) problem introduction, (3) explore students' prior knowledge, (4) group or individual division, (5) investigation and research, (6) analysis and evaluation of information, (7) identification of solutions or alternatives, (8) discussion and collaboration, (9) solution implementation, (10) evaluation and reflection, (11) application in real context, and (12) discussion and presentation (Hung, 2009; Susilawati & Supriyatno, 2023; Wasson & Kirschner, 2020). Through these steps, problem-based learning in primary schools can encourage students' active engagement, develop critical and creative thinking skills, and provide a deep understanding of the subject matter in a real context.

Problem based learning has a number of advantages and benefits that make it an effective and relevant learning approach in the context of 21st century education. Problem based learning encourages students to think critically in finding solutions to the problems at hand. They must analysis information, evaluate alternatives, and formulate evidence-based arguments (Partono et al., 2021). Students become the centre of the learning process (Yulianti et al., 2022). They take an active role as learners who raise questions and seek answers to the problems faced. According to Li (2013) problem based learning helps develop lifelong learning skills, such as research skills,

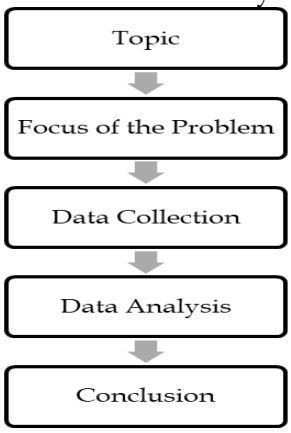
information gathering, and critical evaluation. Students also learn to search for answers and solutions independently.

Based on this background, it shows the influence of the application of problem-based learning models on students' critical thinking skills. It can be concluded that critical thinking skills can be developed and even shaped through the learning process based on the application of problem-based learning models. Some of them are contained in the results of research with the study of the effect of problem-based learning models on critical thinking skills at various levels of education, showing significant positive effects and outcomes (Anugraheni, 2018; Cholik et al., 2022; Dakabesi & Luoise, 2019; Evi & Indarini, 2021; Febrina & Airlanda, 2020; Kamil et al., 2019; Phasa, 2020; Rossytasari & Setyaningtyas, 2021; Yohannes et al., 2021). From several studies that have been conducted, there is still no study with a focus on the application of Problem Based Learning to students' critical thinking skills in elementary schools in a complete and comprehensive manner, especially in Indonesia. Therefore, to illustrate the impact of problem-based learning models on critical thinking skills among elementary school students in Indonesia, this meta-analysis study represents the first attempt to analyze the effect of implementing problem-based learning models on the critical thinking skills of elementary school students in Indonesia. With this research, a complete description and picture of the effect of the Problem Based Learning model on the critical thinking skills of elementary school students in Indonesia will be obtained.

METHOD

The research method used in this study is quantitative through a meta-analysis approach. Meta-analysis is a statistical technique with a research approach that uses secondary data from other relevant quantitative research results (Israel, 2011; Petitti, 2001). Meta-analysis can be used as an approach in research to integrate and interpret data from relevant research results in a particular field (Field & Gillett, 2010; Shelby & Vaske, 2008). The research methodology for meta-analysis is as follows:

Figure 1. Flowchart of Meta Analysis Research Methodology

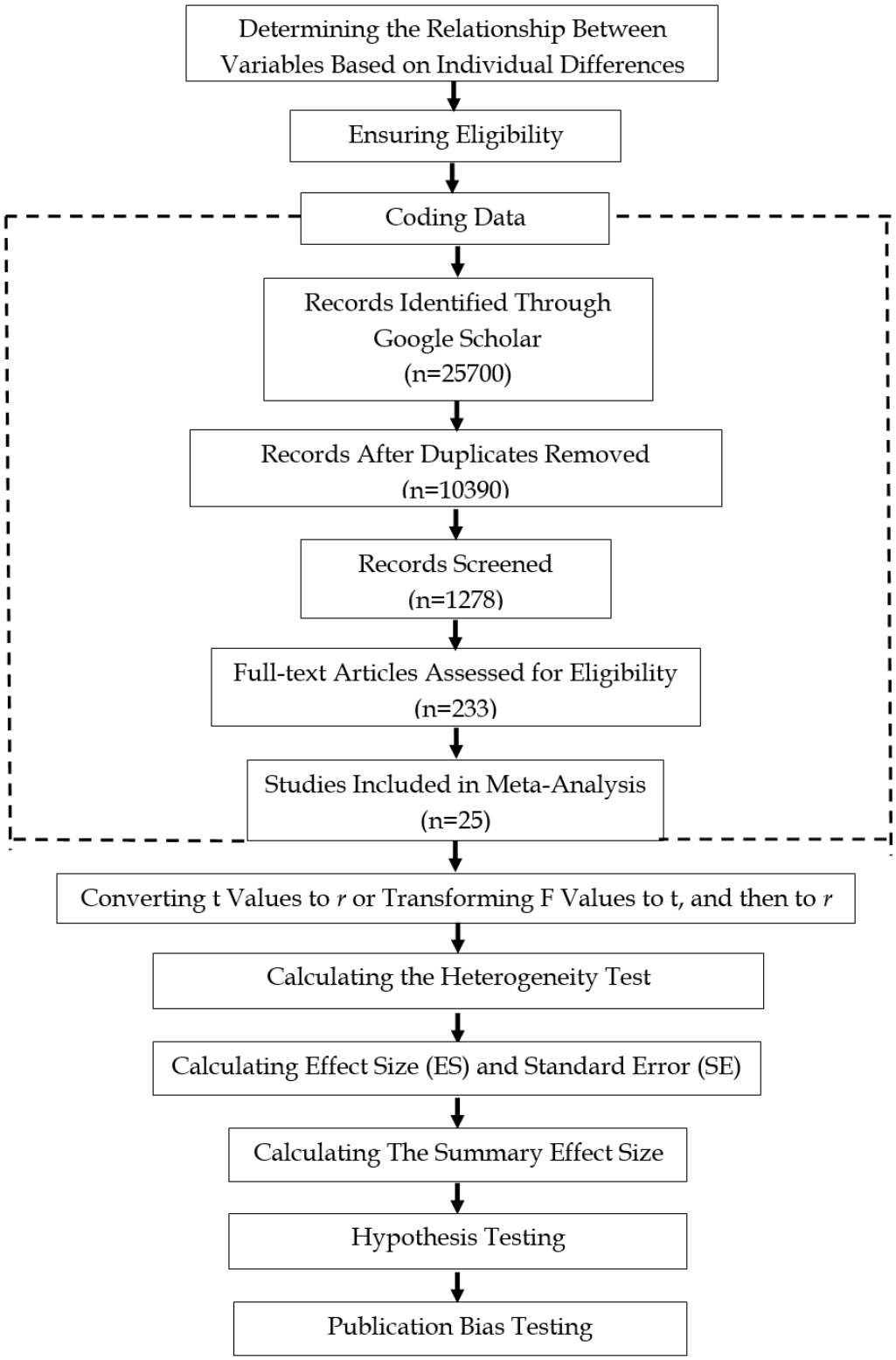


Meta-analysis has several stages, namely 1) Aiming at the theme, 2) Creating an overall design, 3) Finding research samples, 4) Collecting data, 5) Analysing data (Handayani & Koeswanti, 2021). This study examines the effect size of several studies that have been studied regarding the effect of the problem-based learning model on students' critical thinking skills with the scope of study at the elementary school level.

The results of relevant research used as study material in this study use several inclusion criteria as determinants, including: (1) publications can be traced through Google Scholar, (2) publications indexed by SINTA. Sinta (Science and Technology Index) serves as the journal indexing system for the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia, categorizing journals into six tiers (S1 to S6) (Fitria, 2023), (3) the scope of publications related to the problem-based learning model on critical thinking skills, (4) publications related to the results of research conducted on elementary school level subjects, (5) publications related to the results of research on elementary schools in Indonesia, (6) publications include the value (r), (t) or (F), (7) publication of research articles published in the range of 2014 to 2022. According to Wilson and Kelley, one of the steps in conducting a meta-analysis is to determine the range of the study period used as the source data (Merriyana, 2006).

By determining the study period for the research results used, a comprehensive overview of the research conducted within that timeframe can be provide, (8) publications must have N ≥ 20. Referring to the guidelines of Article 24 of Permendikbud No. 17 of 2017, the minimum number of students per class at the elementary school level is 20 (Nafiah & Suyanto, 2014; Perdana et al., 2020). According to Tamur (Tamur et al., 2020), the sample size category is determined by the tendency of the collected data. The larger the sample analyzed by combining data from several studies, the more precise and robust the accuracy of the analysis results. These criteria are taken into consideration in compiling the coding of research data used and interpreted in meta-analysis research. The conversion calculation was carried out if the research results used only listed one of the t or r values with the procedure of transforming the t value to r or transforming the F value to t, then to r. The steps in the research data analysis include several stages (Chamdani et al., 2022), as follows:

Figure 2. Flowchart of The Steps Data Analysis (Moher et al., 2010)



The following are the results of the coding of the meta-analysis research data used.

Table 1. Data Analysis

No.	Year	Author	Index	N	r	t	F
1.	2016	Imron	Sinta 4	30		13,377	
2.	2019	Aiman et.al.	Sinta 4	50			14,944
3.	2022	Fauziah&Fitria	Sinta 3	40		2,267	
4.	2022	Susilowati et.al.	Sinta 3	21		12,457	
5.	2020	Saputro & Rahayu	Sinta 5	50	0,898		
6.	2021	Batubara et.al.	Sinta 4	29	0,852		
7.	2019	Sutrisno	Sinta 3	60		3,730	
8.	2018	Widiani	Sinta 5	90		3,020	
9.	2022	Haryanti et.al.	Sinta 2	49			13,627
10.	2018	Purbarani et.al.	Sinta 6	58			10,683
11.	2022	Wati & Anugraheni	Sinta 3	47		4,511	
12.	2018	Helmon	Sinta 4	60		6,685	
13.	2022	Risnawati et.al.	Sinta 4	48		11,445	
14.	2021	Hasna et.al.	Sinta 2	26		8,829	
15.	2020	Rahmatia & Fitria	Sinta 5	56		2,01	
16.	2014	Christiana et.al.	Sinta 3	63		2,11	
17.	2020	Utami & Giarti	Sinta 5	110		2,305	
18.	2021	Cristanti et.al.	Sinta 5	59		3,389	
19.	2020	Misla & Mawardi	Sinta 2	72		3,992	
20.	2020	Ati & Setiawan	Sinta 3	62		2,810	
21	2021	Sasmita & Harjono	Sinta 3	46		10,201	
22	2020	Verinsyah & Fitria	Sinta 4	32		2,36	
23	2022	Levina et.al.	Sinta 3	42			6,286
24	2020	Prasetyo & Kristin	Sinta 3	47		2,863	
25	2021	Prayoga & Setyaningtyas	Sinta 3	40		6,942	

The research data analysis technique is assisted by JASP 0.8.5 version software to calculate the effect size, summary effect, heterogeneity test, normality test, and standard error and forest plot visualization. The size effect criteria refer to Cohen's Effect Size as follows.

Table 2. Cohen's effect size criteria (Cohen, 1988)

Value	Criteria
< 0 + / -.1	Weak effect
< 0 + / -.3	Modest effect
< 0 + / -.5	Moderate effect
< 0 + / -.8	Strong effect
≥ + / -.8	Very strong effect

RESULT AND DISCUSSION

Based on the 25 articles reviewed with specifications at the primary school level and the scope of the study of research results in Indonesia, the effect of the Problem Based Learning model on students' critical thinking skills can be analyzed. The study sample based on 25 articles amounted to 1287 in the range of grade II to grade VI elementary schools. Based on the results of the heterogeneity test of 25 research results analyzed with the help of JASP software.

Table 3. Heterogeneity Test Results

Fixed and Random Effects			
	Q	*df*	p
Omnibus test of Model Coefficients	58.133	1	< .001
Test of Residual Heterogeneity	210.132	24	< .001

The results of the analysis showed that the 25 research articles used had a statistical value of Q = 210.132. The p value <0.001 with a sig level. 0,05 (95% α 0,05). The results of the analysis of the statistical value of Q and the p value of heterogeneity indicate that each research article analyzed and tested shows heterogeneous data. The heterogeneity test results are supported based on the heterogeneity measure.

Table 4. Heterogeneity Test Results

Residual Heterogeneity Estimates			
		95% Confidence Interval	
	Estimate	Lower	Upper
τ^2	0.196	0.112	0.423
T	0.443	0.335	0.650
I^2 (%)	90.450	84.412	95.324
H^2	10.471	6.415	21.385

Based on the results of residual heterogeneity estimates, the variance between study effect sizes ($\tau 2$) using the Dersimonian Laird estimator is 0.196 and the standard deviation between studies (τ) is 0.443. The analysis shows a value of $\tau 2 > 0$ or $\tau > 0$ which indicates that each study used is heterogeneous. The resulting heterogeneity is on a high-scale index with an I^2 (%) value close to 100%, which is 90% with a confidence interval between 84.412% - 95.324%. Thus, the 25 studies used are heterogeneous and can be applied in the next stage of the random effect model test using the summary effect size test.

Table 5. Effect Size Summary

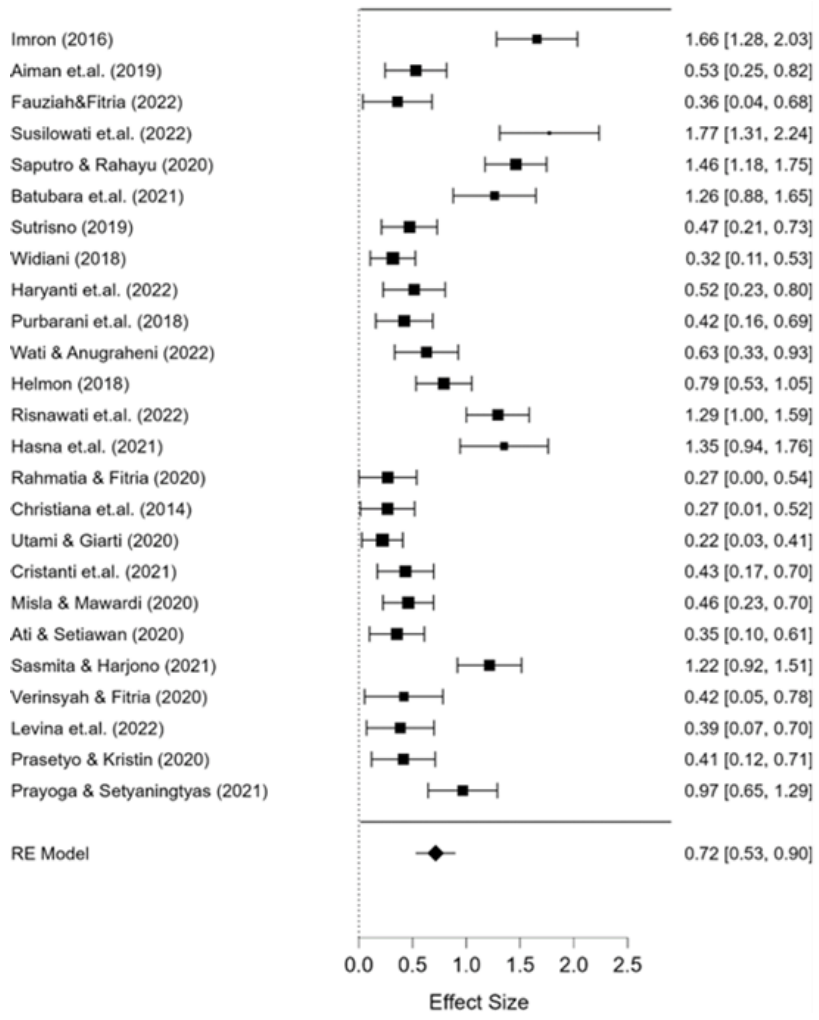
Coefficients						
					95% Confidence Interval	
	Estimate	Standard Error	z	p	Lower	Upper
Intercept	0.715	0.094	7.625	< .001	0.531	0.899

The results of the analysis using the random effect model with the calculation of the summary effect size test showed that there was a significant positive influence between the problem-based learning model and students' critical thinking skills (z =

7.625; p-value <0.001; 95%CI [0.531; 0.899]). The effect of the problem-based learning model on students' critical thinking skills based on Cohen's summary effect size criteria is included in the strong category with a positive standard estimate of 0.715 and a standard error of 0.094. Based on the calculated results, it shows that there is a positive effect of the problem-based learning model on critical thinking skills.

The results of the summary effect test calculation are illustrated through the results of the forest plot test. Forest plot test to determine the level of consistency of the effect size of each study used. The results of the forest plot analysis were able to show the lowest and the highest values of the 25 studies in the meta-analysis.

Figure 3. Forest Plot Test Result

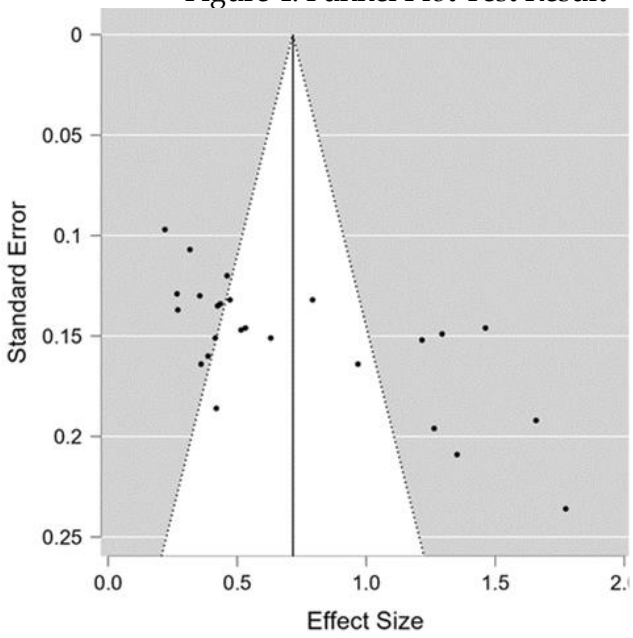


According to the forest plot analysis data, it can be observed that the effect size of the analyzed article studies varies between 0.22 and 1.77. The magnitude and direction of the forest plot results as the correlation value of each study studied in this study has black dots with a fairly wide and large distribution, and the whole tends to be in the direction of the line to the right of the criterion point. The results of the forest plot on the right side of the aggregate boundary line indicate that each study has a significant effect size. The random effect size value is 0.53 to 0.90 and the median value is 0.72, indicating a 72% difference in comparison between learning that applies the Problem-

Based Learning model and the application of conventional learning models or other learning models.

The results of calculations and analysis between the application of problem-based learning models to critical thinking skills according to several article studies have a positive correlation value. The results of the effect size test analysis of 25 research articles analyzed need to be tested for publication bias. Publication bias test with the help of funnel plot test.

Figure 4. Funnel Plot Test Result



The funnel plot analysis results indicated that there was no empty black round distribution and indicated that each study reviewed did not have publication bias. The results of the publication bias test are supported by the results of the file drawer analysis in the fail-safe N test. The fail-safe N test results are as follows.

Table 6. Fail-Safe N Test

File drawer analysis			
	Fail-safe N	Target significance	Observed significance
Rosenthal	4813.000	0.050	< .001

Based on the table analysis, it showed that K=25, so 5K+10=5(25) +10=135. The fail-safe N value obtained is 4813, with a target sig. 0.05 and p value <0.001. Since the value of fail-safe N>SK+10, it can be concluded that there is no publication bias problem in the meta-analysis study. Thus, there is no publication bias in the meta-analysis study of the problem-based learning model on students' critical thinking skills in elementary school.

DISCUSSION

The heterogeneity test was conducted as an initial stage of the requirements for calculating the standard error and effect size of meta-analysis research (Higgins, 2008). Based on 25 research articles that have various research sampling, the heterogeneity test uses fixed and random effects (Jackson, 2006; Poole & Greenland, 1999; Tong &

Guo, 2019). The heterogeneity test results showed that each study used had heterogeneous results with a statistical value of Q = 210,132 and p value <0.001. The heterogeneity on a high-scale index with an I^2 (%) value of 90% was found.

The next stage is to determine the results of the general summary effect size to be observed with the help of the summary effect test of the random effect size model (Borenstein et al., 2010; Brysbaert & Stevens, 2018). The random effect meta-analysis model is a method generally recommended to combine several different research variations (Ades et al., 2005; Henmi & Copas, 2010; White, 2009). The results of the summary effect calculation show a positive correlation between the problem-based learning model and critical thinking skills with a positive estimate value of 0.715 and a standard error of 0.094.

The correlation value indicated in the forest plot results which provides information on the level of consistency of the effect size of each research result used (Fisher, 2015; Neyeloff et al., 2012; Shi et al., 2017). Effect size is used to calculate the statistical power of significance tests and to compare the effects of a research variable using different measurement scales (Aloe, 2014; Santoso, 2010; Schäfer & Schwarz, 2019). The effect size results can provide an interpretative report on the magnitude of a study's effect, thereby strengthening the P value (Aarts et al., 2014; Sullivan & Feinn, 2012). The lowest effect size value is 0.22 and the highest effect size value is 1.77 with a summary effect value of 0.72. While the distribution of black dots on the forest plot is to the right, the higher the level of significance of each study used (Dettori et al., 2021; Verhagen & Ferreira, 2014).

The validity of the conclusions of the effect size analysis results was supported by the results of the funnel plot analysis test as a publication bias analysis based on 25 articles (Lin & Chu, 2018; Peters et al., 2006). The funnel plot test is used as a method for detecting publication bias. The results of a funnel plot, which show a symmetrical or asymmetrical shape along with the summary effect, can serve as a guide to determine whether the research results indicate publication bias or not (Duval & Tweedie, 2000; Sedgwick, 2013). The funnel plot results are based on the accuracy of estimating the effect size will increase as the number of sample study components increases (Egger et al., 2017). Based on the funnel plot results, a study is not indicated to have publication bias if the funnel plot shape is symmetrical with the summary effect. The analysis of publication bias was clarified by the fail-safe N analysis. Publication bias is an important analysis sfor meta-analysis because it can cause bias in systematic review conclusions (Lin et al., 2018). The possibility of unpublished research because the results do not reach the significance value causes publication bias (Sutton et al., 2000). Based on the funnel plot results, the study does not indicate publication bias if the funnel plot is symmetrical with the summary effect. The safe N file analysis test in the drawer file shows that 4813 related studies are suspected of having biased results so they were not published.

Thus, the results of the analysis of 25 articles that have been reviewed showed a positive correlation between the application of the problem-based learning model and critical thinking skills in elementary school students. The teachers' demand to create a learning atmosphere where students become the center of learning will lead to the formation and improvement of skills and attitudes that are expected to be established through learning activities (Abidin, 2017; M.Ilyas & Syahid, 2018; Mahmudah, 2018). Education orientation as mandated in the national education goals aims to be able to form students to have balanced competence and knowledge (Malik, 2018; Rais, 2019). These two main elements are the basis for the preparation of learning outcomes and

graduates who are expected to be able to meet the needs of modern society in the 21st century.

Learning models influence the success of the learning process (Khoerunnisa & Aqwal, 2020; Mirdad, 2020; Santosa, 2018). Active learning is designed to be integrated between the application of various types of learning models with interesting learning media and resources (Abdullah, 2017; Widoyo et al., 2023). Such learning activities can create motivation and active student participation in learning activities. Among these learning models is the problem-based learning model. The problem-based learning model can be one of the learning designs to support the fulfillment of students' 21st century competencies and skills, especially critical thinking skills.

Problem based learning, as a learning model, fosters learning activities that require students to engage in deep and comprehensive thinking activities (Kim et al., 2019). The implementation of problem-based learning at the elementary school level, targeting students aged 7 to 12 years according to Piaget's developmental stages, focuses on systematic thinking. This learning concept involves presenting problems and guiding students in finding solutions (Saepuloh et al., 2021; Snyder & Snyder, 2008). Learners are required to analyze information, evaluate alternatives, and formulate arguments (Lapuz & Fulgencio, 2020; Monalisa et al., 2019). The application of the problem-based learning model is grounded in learning activities that provide students with real-life experiences, serving as stimuli for applying their knowledge and skills to analyze problems (Rokhimawan et al., 2022; Savery, 2006). This model encourages students to think critically in order to identify solutions to the problems they encounter (Maulana et al., 2022; Suwastini et al., 2021). Utilizing the problem-based learning model effectively directs learning activities that help students identify the various elements necessary to solve the problems they encounter (Ahdhianto et al., 2020; N. Jannah, 2022). These learning activities require students to possess the ability to comprehend and process the material they have learned through analytical thinking skills, which involve connecting multidisciplinary knowledge with real-world situations. Analytical thinking is a critical thinking activity that demands a high level of self-competence in thinking (Maksum et al., 2021; Nurfaizah et al., 2022). Critical thinking is considered a cognitive skill and is recognized as one of the essential 21st century competencies for navigating dynamic life in society (Asri et al., 2023; Harahap et al., 2020; Saputra et al., 2019). The mastery of critical thinking skills, when taught and practiced early on, has broad implications for students' preparedness to thrive in the 21st century.

The current research findings further conclude that in enhancing students' critical thinking skills, educators can implement various learning models that require students to engage in analytical activities through stages of thinking (Cahyani et al., 2021; L. Jannah et al., 2023; Khaeruddin et al., 2023; Mareti & Hadiyanti, 2021; Rahmadani, 2019; Rohmawati & Fathoni, 2022; Samura, 2019; Wiguna et al., 2023). The application of various types of learning models that align with the learning objectives and materials that is delivered to students can support effective learning activities to achieve the three domains of educational goals, namely cognitive, affective, and psychomotor learning objectives. The utilization of problem-based learning models in the learning process can enhance students' critical thinking skills (Ruli & Indarini, 2022; Sukmawati, 2020). Thus, based on several research findings, it can be concluded that the implementation of problem-based learning models can enhance students' critical thinking skills at the elementary school level.

Problem-based learning models assume the perspective that the learning process revolves around students engaging in problem analysis activities and constructing assumptions for problem solutions based on experimental studies (Jonassen, 2011; Knöpfe et al., 2024). In the application/implementation of problem-based learning models, accompanied by collaborating learning activities between teachers and students in the process of designing problem-solving schemes (Almulla, 2020; Yew & Goh, 2016). Designing the learning process through analytical activities can create a space for learning that encourages and enhances students' critical thinking skills. Critical thinking skills entail a cognitive process to analyse problems systematically and specifically, distinguish problems accurately through identification the information and examination to plan problem-solving strategies (Alsaleh, 2020; Azizah et al., 2018). The results of meta-analysis research presented the hypothesis suggest a relationship or correlation between the implementation of problem-based learning models and students' critical thinking skills.

Based on the research findings, it is evident that the problem-based learning model applied in the learning process can enhance students' critical thinking skills. Problem-based learning models applied at the elementary school level can contribute to train students from an early age to identify and solve various problems by developing analytical abilities and drawing conclusions to formulate solutions. Teaching that directs students to build their problem-solving abilities would foster the development of students' critical thinking skills. The practical implications of this research provide integrated and contextual learning experiences by inviting students to solve relevant real-life problems. Students are confronted the challenges that require them to apply the knowledge they have learned in new and complex situations. It can stimulate students to develop their critical thinking skills through activities such as analysis, evaluation, and problem-solving. Theoretical implications suggest that problem-based learning models are based on constructivist views that emphasize active learning for students constructing their knowledge through experience and reflection. By presenting challenges to solve real-life problems, students will develop the knowledge deeper and sustainable through the analytical thinking process they employ.

The limitation of this research lies in using only elementary school students as research subjects. The study's limitations include using the distribution of research results on the implementation of problem-based learning models for critical thinking skills at the elementary school level with a limited sample only in Indonesia through meta-analysis methods. The analysis results using meta-analysis methods are limited to quantitative research data which solely based on statistical figures only.

Therefore, it is recommended for future research to examine research results at the elementary school level not only in Indonesia but in several other countries. It is recommended for future researchers to examine research results on the theme of problem-based learning models with the scope of higher levels, including middle school, high school, and university levels. To strengthen and support research data quantitatively, qualitative data can be used by combining literature review study methods (SLR) and integrating meta-analysis methods to make the research results more comprehensive.

CONCLUSION

Based on the results of research from 25 published articles, it can be concluded that there is a strong influence of the problem-based learning model on the critical

thinking skills of elementary school students in Indonesia. The analysis of heterogeneity showed a high level of heterogeneity and the validity of the funnel plot analysis was supported by the fail-safe N test, indicating no publication bias in the meta-analysis of the problem-based learning model's impact on critical thinking skills. The results of the meta-analysis research support previous research and theories regarding the implementation of the problem-based learning model's influence on critical thinking skills. Therefore, it can be concluded that the implementation of problem-based learning models in the educational process at the elementary school level has a strong impact on the development and enhancement of students' critical thinking skills from an early age. However, the limitations of this research include the subject's educational level and geographical factors, as it only focused on elementary school research in Indonesia. Therefore, future research recommendations could involve comparing different educational levels in various countries using broader research data.

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HS contributes to conceptualization, analysing, and script writing. LEWD contributes to disscussed designing research and processing research results. SA, UH contributes to searching relevant articles and coding data. RH, MS contributes to reviewing and final approval script.

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