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The Effect of Problem-Based Learning Model on Mathematical Critical Thinking Skills of Junior High School Students: A Meta-Analysis Study

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Abstract

Numerous similar studies have been conducted to evaluate the effect of problem-based learning models (PBL) on students' mathematical critical thinking skills. However, the findings from these studies are inconsistent. Highlighting this gap, this study comprehensively evaluates the effectiveness of implementing the PBL model on junior high school students' critical thinking skills. This meta-analysis study was conducted by analyzing a sample of 15 journal papers that met the feasibility. Empirical data collection uses several journal search engines, and the instruments used are coding categories. Data analysis to obtain effect size value was performed with Comprehensive Meta-Analysis (CMA) software, and the estimation method used a random-effect model. Overall, the results showed that the effect size of PBL model implementation on mathematical critical thinking skills of junior high school students is 0.970, which means the PBL model's implementation had a high effect on students' critical thinking skills. Besides, the effect size of implementing the PBL model on junior high school students' critical thinking skills did not differ based on differences in class, year of study, and sample size. However, there were significant differences in effect sizes between study groups based on treatment duration. Thus, PBL will achieve a higher level of effectiveness, taking into account the treatment duration.

Keywords: A meta-analysis, effect size, critical thinking, problem-based learning, junior high school.

Abstrak

Sejumlah penelitian serupa telah dilakukan untuk mengevaluasi pengaruh model Problem-Based Learning (PBL) terhadap kemampuan berpikir kritis matematis siswa. Namun, temuan dari penelitian-penelitian tersebut tidak konsisten. Menyoroti kesenjangan tersebut, penelitian ini bertujuan mengevaluasi secara komprehensif efektivitas penerapan model PBL terhadap kemampuan berpikir kritis siswa SMP. Studi meta-analisis ini dilakukan dengan menganalisis 15 sampel artikel jurnal yang memenuhi kelayakan. Pengumpulan data empiris dilakukan menggunakan beberapa mesin pencari jurnal, dan instrumen yang digunakan adalah lembar kategori pengkodean. Analisis data untuk mendapatkan nilai effect size dilakukan dengan asistensi dari program Comprehensive Meta-Analysis (CMA), dan model estimasi yang digunakan adalah model efek acak. Secara keseluruhan, hasil penelitian menunjukkan bahwa effect size penerapan model PBL terhadap kemampuan berpikir kritis matematis siswa SMP adalah 0,970, yang berarti penerapan model PBL berpengaruh tinggi terhadap kemampuan berpikir kritis siswa. Selain itu, ukuran pengaruh penerapan model PBL terhadap kemampuan berpikir kritis siswa SMP tidak berbeda berdasarkan kelas penelitian, tahun penelitian, dan ukuran sampel. Namun, terdapat perbedaan yang signifikan pada ukuran efek antar kelompok studi berdasarkan durasi perlakuan. Dengan demikian, PBL akan mencapai tingkat efektivitas yang lebih tinggi dengan mempertimbangkan durasi perlakuan.

***Kata Kunci**: Meta-analisis, ukuran efek, berpikir kritis, pembelajaran berbasis masalah, sekolah menengah pertama.*

Introduction

Nowadays, learning in schools is increasingly leading to learning activities that require students to be active (student-centred). The aim is to train students to develop higher-order thinking skills as well as other relevant skills. Moreover, in the 21st century, students are expected to have 4C skills, namely critical thinking, creative thinking, communication, and collaboration. Critical thinking skills, as one of the 4C skills, are an essential competency. Critical thinking skills are currently a concern in classroom learning and have begun to be widely studied because of their significant role in decision-making.

Critical thinking skill is one of the 21st century competencies that are fundamental and needs to be mastered by humans today (Bishop, 2009; Lamb et al., 2017; Schlegel, 2011). Critical thinking skill becomes an ability that must be possessed to be a qualified human resource (UNESCO, 2011; Uribe-Enciso et al., 2017). Critical thinking is described as the process of reflective thinking, which is part of the ability to think at a higher level in stages of review involves forming arguments with relevant evidence, concluding, and using information held to solve problems (Beyer, 1995; Dewey, 1909; Facione, 2015; Hafni & Nurlaelah, 2018). Besides, mathematical critical thinking ability can also be interpreted as a person's ability which includes: explaining with reasons, focusing on determining what is believed, the ability to generalize, prove, and evaluate situations reflectively, distinguish between relevant and irrelevant things, identify and evaluate situations, analyze assumptions, identify biases and views, and access evidence (Marlina & Harahap, 2018). In addition, by having critical thinking, a person will own and evolve other skills such as high attentiveness, analytical skills, and improved thought processes (Changwong et al., 2018; Roekel, 2016).

If it is associated with mathematics, mathematical critical thinking skills can be defined as the ability to think to integrate new knowledge with existing knowledge, reasoning abilities, and apply cognitive understanding in mathematical problem-solving situations (Widyatiningtyas et al., 2015; Yuwono et al., 2019). Therefore, mathematical critical thinking skills will be instrumental in solving a problem with a mathematical atmosphere and directly affect a person's critical thinking in dealing with a problem requiring problem-solving solutions with logical and systematic steps.

Improving students' critical thinking skills is closely related to the implementation of the learning model carried out in the classroom. The learning steps taken by the teacher in the classroom will be able to hone students' critical thinking skills if implemented maximally and adequately. The learning model that is widely used today also adapts to the demands of 21st-century competencies. Therefore, it is hoped that the output of the learning will also produce qualified and competitive individuals. The learning model that is quite popular and has been widely studied because of its role in significantly improving students' critical thinking skills is the Problem-Based Learning model. This model is one of the models suggested by the government in the national curriculum to be implemented in learning in schools because this model is expected to be able to form students who have 21st-century competencies.

Problem-Based Learning (PBL) is a learning model oriented to using problems with real-world contexts that can practice critical thinking and problem-solving ability and a comprehensive understanding of a material concept (Arends, 2015; Herman, 2007). PBL can hone critical thinking skills because this model includes steps of activities that require students to carry out discussion, exploration, inquiry, discovery, and problem-solving (Galand et al., 2012; Morales-Mann & Kaitell, 2001; Sunaryo, 2014; Zamzam, 2016). In other words, the learning steps with this PBL model potentially can improve students' mathematical critical thinking skills. In addition, the use of contextual problems that are close to students' daily lives will also train them to think critically to find the best solution to these problems.

Many primary studies have been carried out in Indonesia to assess the PBL model's effect on junior high school students' critical thinking skills. Previous studies revealed that the implementation of PBL could enhance junior high school students' critical thinking skills (Arifin et al., 2015; Hakim et al., 2014; Ilham, 2018; Islahuddin et al., 2018; Marinda et al., 2018; Noer & Gunowibowo, 2018; Nurafiah et al., 2013; Putri & Fauzan, 2019; Sari et al., 2014; Sari et al., 2019; Sirait, 2019; Steven et al., 2019; Susanti & Suwu, 2016; Warmi, 2017; Waspadany et al., 2016; Yanti & Prahmana, 2017). However, the findings of the various studies are inconsistent, and the results in these studies do not yet include the value of the effect size of the PBL on students' critical thinking skills. Thus, a comprehensive evaluation of the effectiveness of the PBL on students' critical thinking skills can be an alternative basis for decision making by the government or educational institutions for implementing this model in the learning process.

The effectiveness of implementing the PBL model to the junior high school students' critical thinking skills and the possible effects of study characteristics that cannot be answered in primary studies can be re-analyzed using higher analysis, namely the meta-analysis method. The meta-analysis method is a secondary analysis method that is understood as an analysis over-analysis. The overall evaluation is carried out using quantitative data obtained in independent studies that are then analyzed statistically (Borenstein et al., 2009; Radin, 2009). In addition, meta-analysis develops a technical analysis that can help researchers examine the consistency or inconsistency of the cross-sectional study of similar studies (Borg & Gall, 1983). Thus, the meta-analysis method focuses on analyzing identical research results with the researcher's inclusion criteria.

Previous meta-analysis studies of the PBL model have been conducted to analyze the effectiveness of implementing the PBL model (Dochy et al., 2003; Gijbels et al., 2005; Miterianifa et al., 2019; Walker & Leary, 2009) to students' mathematical abilities (Anugraheni, 2018; Asror, 2016; Mustaffa et al., 2014). All of these studies found that implementing PBL was more effective than educator-centred learning. Dochy et al. discovered that PBL was more beneficial for applying knowledge (Dochy et al., 2003). However, their study was also still limited to the characteristics of the research design, field of implementation, level of student expertise, retention period, and type of assessment. Gijbels et al., in their study, only focused on looking at the effectiveness of PBL on problem-solving ability and did not discuss the characteristics of the study (Gijbels et al., 2005). Walker & Leary states that PBL is better used on subjects other than Medical Education (Walker & Leary, 2009). However, their meta-analysis findings were still limited to the criteria used, namely the type of problem, implementation, discipline, and assessment level.

Meanwhile, the study conducted by Miterianifa et al. was limited to physics, biology, and chemistry (Miterianifa et al., 2019), while the Anugraheni study was still limited to the elementary school level (Anugraheni, 2018). Furthermore, a study conducted by Asror (2016) only discussed the effect of study characteristics, namely the level of education, subject matter, learning media, and mathematical skills. Lastly, the study conducted by Mustaffa et al. (2014) was limited to education levels. Therefore, it is necessary to conduct a comprehensive study to analyze the PBL model's effectiveness in junior high school students' mathematical critical thinking skills. Besides that, the effectiveness of using the PBL model to students' critical thinking skills based on the class of study, year of study, duration of treatment, and sample size characteristic is also needed. Thus, the results of this meta-analysis are expected to provide a uniform view of the findings as a whole.

Methods

This study is a systematic literature review using meta-analysis methods. The population used in this study is the indexed national journal of mathematical education such as google scholar, portal

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garuda, ERIC, and the direct URLs of national journals regarding the effect of the PBL model on mathematical critical thinking skills of junior high school students in the year range of 2013-2020 (last seven years). The sample used was 15 mathematics education research articles obtained from the selection based on inclusion criteria. This study's data collection techniques are Search Engines of Google Scholar, Portal Garuda, ERIC, and national journals' URLs. The stages of meta-analysis used in this study are adapting the meta-analysis steps described by DeCoster and presented in the diagram in Figure 1 (Decoster, 2009).

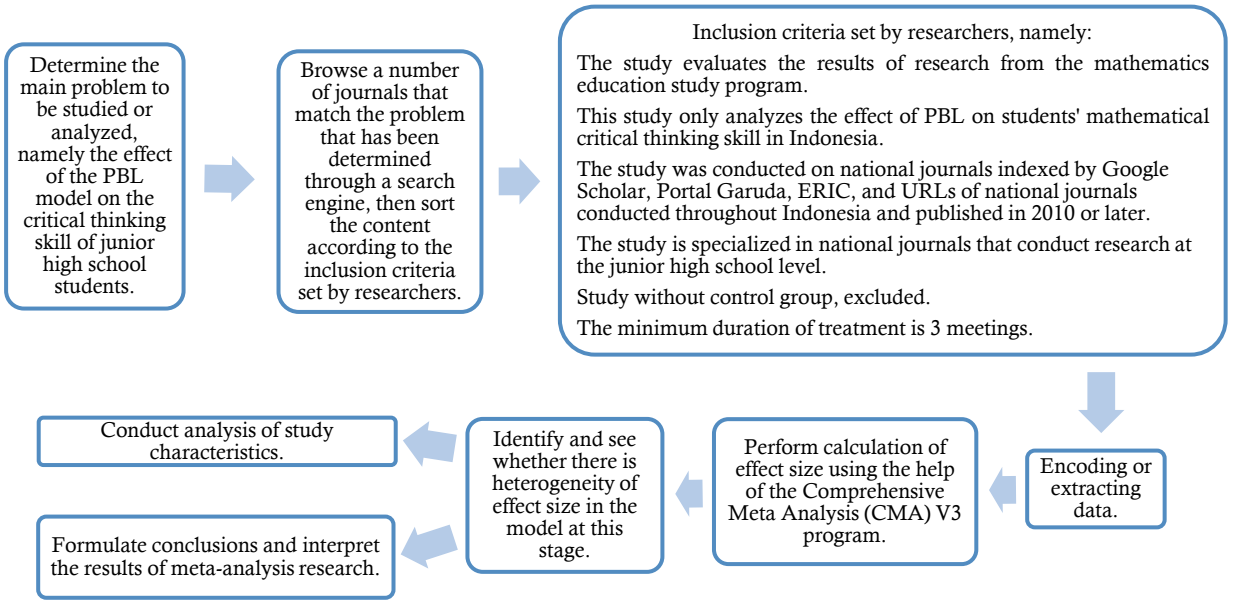

Figure 1. Steps of Meta-analysis

During the search and selection of studies to be included in the meta-analysis, the researchers selected studies using a coding protocol sheet instrument that had been validated and contained information about the inclusion criteria that had been previously determined. Furthermore, after the study selection process is complete, the data extraction process is carried out. This process is carried out by the researcher and a coder so that the empirical data extracted from the primary study is valid, obtained through the results of the inter-reliability test (IRR). In this test, the interpretation of the agreement value between coders is a good agreement category so that the data can be used for further analysis. This step is crucial to be considered by a meta-analysis method researcher because it relates to the rigorous quantitative research process and is closely related to the reliability of the analysis results.

The meta-analysis method is quantitative and is closely related to the use of effect size (ES). Effect size represents the impact strength between the dependent and independent variables, and the value can be compared between studies. The relationship between variables discussed in this study is the relationship between the class of study, year of study, sample size, duration of treatment, and its effect on the effectiveness of PBL in enhancing junior high students' critical thinking skills. The effect size (ES) calculation was calculated using the Hedges' g formula (Borenstein et al., 2009), which is the development of the effect size formula proposed by Glass (1981). The effect size calculation process was done using the assistance of the Comprehensive Meta-Analysis (CMA) program. The CMA Program can process the empirical data, such as mean, standard deviation, sample size, t-value, and p-value, which later will be used as the effect size values. Furthermore, the effect size will be interpreted with the effect size category (Glass et al., 1981) in Table 1.

Table 1. Effect Size (ES) Category

Effect Size (ES)	Effect Size Category
ES ≤ 0.15	negligible effect
0.15 < ES ≤ 0.40	small effect
0.40 < ES ≤ 0.75	moderate effect
0.75 < ES ≤ 1.10	high effect
1.10 < ES ≤ 1.45	very high effect
1.45 < ES	high influence

Another fundamental analysis that must also be performed in a meta-analysis study is to conduct a publication bias test. This test is necessary to anticipate the tendency that studies published by journals exclusively are studies with significant findings, making the effect size obtained too high than the actual effect size (Borenstein et al., 2009). The publication bias test can be done by looking at the Funnel Plot results, Rosenthal's fail-safe N (FSN), and the Trim and Fill test (Kul et al., 2018). First, there is no bias if the studies' effect size scatters symmetrically around the funnel plot's combined effect size (Borenstein et al., 2009). Then, if the FSN result obtained from the formula N / (5k + 10) (note: k is the number of studies involved) is higher than one, then it could be interpreted that all studies involved in the analysis steps are insusceptible to publication bias (Turgut & Turgut, 2018) and the interpretation of the meta-analysis outcomes are reliable (Tamur et al., 2020). The latter, a Trim and Fill test closely related to the funnel plot, was carried out to confirm the number of studies that had to be cut from the analysis to avoid publication bias and excessive effect size interpretation (Borenstein et al., 2009).

After going through the publication bias test, a heterogeneity test will be conducted by looking at the Q-value. If the Q-value is greater than the Q-table, there is heterogeneity of effect size in the primary studies involved. Thus, for further analysis, a random effect model will be used for this heterogeneity. Vice versa, if there is no heterogeneity among effect size distributions, then a fixed effect model will be used. The existence of heterogeneity shows an intervention from the moderator variable (study characteristics) that can be analyzed for the magnitude of the effect and whether the characteristics of the study provide different effects compared to the groups of these variables. Thus, several study characteristics such as class of study, year of study, sample size, and treatment duration will be analyzed to investigate the effect of these characteristics in implementing the PBL model toward Junior High School mathematical critical thinking skills.

Results and Discussion

Results

This meta-analysis study used 20 journals obtained from several indexed search engines such as google scholar, portal garuda, ERIC, and direct URLs of national journals related to the PBL model's effect on junior high school students' critical thinking skills. But based on the specified inclusion criteria, only 15 journal articles were analyzed. Furthermore, the journals analyzed are journals published in the last seven years, namely 2013-2020. The effect size of each journal is presented in Table 2.

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Table 2. Effect Size Category of Journal Analyzed

Journal Code and Author(s)	Effect Size (ES)	Category of Effect Size
J01 (Nurafiah et al., 2013)	1.525	high influence
J02 (Hakim et al., 2014)	0.570	moderate effect
J03 (Sari et al., 2014)	2.729	high influence
J04 (Arifin et al., 2015)	0.656	moderate effect
J05 (Waspadany et al., 2016)	1.867	high influence
J06 (Warmi, 2017)	1.302	very high effect
J07 (Yanti & Prahmana, 2017)	0.611	moderate effect
J08 (Ilham, 2018)	0.763	high effect
J09 (Marinda et al., 2018)	1.686	high influence
J10 (Noer & Gunowibowo, 2018)	0.458	moderate effect
J11 (Islahuddin et al., 2019)	0.476	moderate effect
J12 (Putri & Fauzan, 2019)	0.966	high effect
J13 (Sari et al., 2019)	1.075	high effect
J14 (Sirait, 2019)	1.348	very high effect
J15 (Steven et al., 2019)	0.450	moderate effect
Average effect size	1.041	high effect

According to the table of effect size (ES) above, it is found that there are six studies with moderate effect, three studies with high effect, two studies with a very high effect, and four studies with a high influence. Besides, based on the fixed-effects model, the effect size combination of the PBL model on junior high school students' critical thinking skills as a whole is 1.041 and categorized as a high effect.

The next step in the meta-analysis method is to conduct a publication bias test to determine if there are systematically different studies from all studies included in the analysis. The publication bias test is done by looking at the funnel plot results and Rosenthal's fail-safe N (FSN) value. The funnel plot diagram is presented in Figure 2.

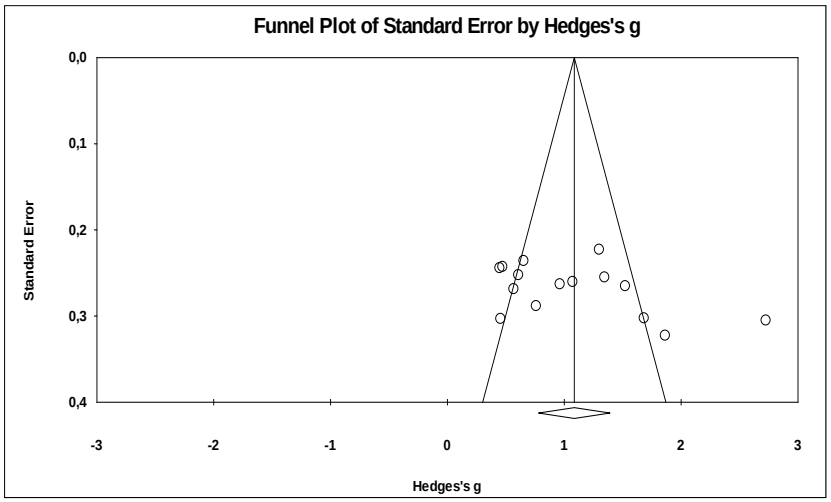

Figure 2. Funnel Plot of Effect Size Distribution

Based on Figure 2, it appears that all effect sizes are scattered asymmetrically. It appears that there is one effect size that is located quite far from the combined effect size. Since the spread of effect size is not fully symmetrical, the FSN value is then identified to calculate the probability of publication

bias. N (FSN) value obtained in CMA software is 929 so that the formula N / (5k + 10) is 929 / (5 * 15 + 10) which is 10.929 greater than 1. The results of this calculation indicate that all studies involved in the meta-analysis were insusceptible to publication bias. Then, to determine whether there are studies that need to be trimmed, a Trim and Fill test is performed. Table 3 shows the Trim and Fill test results.

Table 3. Publication Bias with Trim and Fill Test

	Studies Trimmed	Random Effects			Q Value
		Point Estimate	Lower Limit	Upper Limit	
Observed values		1.086	0.780	1.392	72.310
Adjusted values	1	1.133	0.831	1.436	81.593

Based on Table 3, it is found that there is one study that must be excluded from the analysis, namely the study with code J03. Next, the step taken is identifying the heterogeneity of the effect size distribution. Based on the CMA output, the heterogeneity value is presented in the following Table 4.

Table 4. Heterogeneity of The Effect Size Distribution

Heterogeneity				
Q-value	df(Q)	P-value	I-squared	Q-table
72.310	14	0.000	80.639	23.685

Table 4 shows that the Q-value of 72.310 is higher than the Q-table value (α = 5%), 23.668. It means there is heterogeneity in the effect size distribution, so the estimation model used in this analysis is a random effect model. The effect size obtained in this random model is 1.086 (high effect category). For the next step, only 14 studies will be used in calculation and analysis. The findings of the analysis of 14 studies are given in Table 5.

Table 5. Effect Size According to Random Effect Model

Model	Number Studies	Z	p	Effect Size and 95% Confidence Interval				
				Hedge's g	Standard Error	Variance	Lower Limit	Upper Limit
Random	14	7.825	0.000	0.970	0.124	0.015	0.727	1.214

In the analysis of 14 studies, the combined effect size obtained due to the random effect model was 0.970 with a high effect category. Thus, it shows that the PBL model's influence significantly affects junior high school students' critical thinking skills.

Subsequent analysis was performed to see the PBL model's effectiveness on students' critical thinking skills regarding the study characteristics of the class of study, year of study, sample size, and treatment duration. Furthermore, 14 journals used were then grouped based on study characteristics, i.e., class of study, namely VII, VIII, and IX; year of study, namely 2013-2016 and 2017-2020; sample size, namely ≤ 30 students and > 30 students; and duration of treatment, namely 3-4 meetings and > 4 meetings. Then, the recapitulation of the analysis results of study characteristics is obtained in the following Table 6.

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Table 6. Summary of Analysis Results Based on Study Characteristics

Characteristic of the Study	Group	Number of Studies	Hedge's g	Test of null (2-Tail)		Heterogeneity		
				Z	p	Between-Classes Effect (Q)	df(Q)	P
Class of Study	VII	2	1.335	6.757	0.000	5.697	2	0.058
	VIII	11	0.925	11.760	0.000			
	IX	1	0.611	2.418	0.016			
Year of Study	2013-2016	5	1.129	9.812	0.000	3.752	1	0.053
	2017-2020	9	0.848	9.570	0.000			
Sample Size	≤ 30 students	5	1.020	7.709	0.000	0.361	1	0.548
	> 30 students	9	0.926	11.182	0.000			
Duration of Treatment	3–4 meetings	2	0.592	3.213	0.001	4.474	1	0.034
	> 4 meetings	12	1.013	13.351	0.000			

According to Table 6, analysis based on the class of study shows that the most significant effect size was found in the study group of class VII with an effect size of 1.335 (very high effect). Then, it was followed by the effect size in class VIII, which was 0.925 (high effect), and class IX, which was 0.611 (moderate effect). Therefore, descriptively, it can be said that the application of the PBL model is more potent in class VII than in class VIII and IX. Then, for the group heterogeneity test based on the characteristics of the study class, Q-value was 5.697, while the Q-table (α = 5%; df = 2) was 5.991.

Meanwhile, in terms of the year of study, it was found that the effect size for the two groups was quite different where the effect size for the 2013-2016 study group was 1.129 (very high effect), and the effect size for the 2017-2020 study group was 0.848 (high effect). Then, for the group heterogeneity test concerning the characteristics of the year of study, the Q-value was 3.752, while the Q-table (α = 5%; df = 1) was 3.841. Furthermore, in terms of the sample size characteristics, it was found that the effect size for the sample size ≤ 30 was 1.020, while for the sample size > 30 students was 0.926. Therefore, both study groups of sample sizes were equally categorized as having a high effect. Meanwhile, for the group heterogeneity test regarding the characteristics of the sample size, the Q-value was 0.361, while the Q-table value (α = 5%, df = 1) was 3.841.

In terms of the duration of treatment characteristics given by researchers when applying the PBL model, the results obtained showed that the effect size for the treatment duration of 3-4 meetings was 0.592 (moderate effect) while for the treatment duration of > 4 meetings was 1.013 (high effect). Meanwhile, for group heterogeneity tests based on the duration of treatment, the Q-value was 4.474, while the Q-table (α = 5%) was 3.841.

Discussion

This study is a part of a systematic literature review with the quantitative approach that uses several research journals about the effect of the PBL model on junior high school students' critical thinking skills. The primary study articles used in the meta-analysis must go through a rigorous selection process to avoid bias and ensure the reliability of the research results. Through a study selection process based on inclusion criteria and an examination of the completeness of the required data from the primary study, 15 articles of the primary study were obtained, which will be processed in the meta-analysis.

The empirical data in the primary study article will be extracted by two coders who understand the concept of meta-analysis to guarantee the reliability of the research process. The results of the analysis of the agreement test between coders show that the extracted data is in the good agreement category so that the data can be used in further analysis. The data will be processed and analyzed through the interpretation of effect size values. The effect size calculation process is carried out with the help of the CMA V3.0 program. Statistical data such as the average value, standard deviation, sample size, t-value, and p-value from the experimental and comparison/control group, will be inputted into the program and then processed into an effect size. In addition, this CMA can also present test results from publication bias so that it can be seen whether there are primary studies that have bias so that significantly different primary studies can be excluded from the analysis process.

According to the initial analysis of the combined effect size calculation, it is obtained that the PBL model had a high positive effect on the mathematical critical thinking skill of junior high school students. However, this value explicitly shows the real meaning as the test on the possibility of publication bias is still needed. Publication Bias Test was conducted using an interpretation of Rosenthal's fail-safe N (FSN) value. It was revealed that all studies involved in the analysis were insusceptible to publication bias, so the results and findings of this meta-analysis were reliable. Then, the interpretation of the Funnel Plot and the Trim and Fill Test results show that there is one systematically different study from all studies included. Then, one different study was trimmed to avoid the impact of bias on the overall analysis results. Bias found in this study can be caused by various factors such as weaknesses in determining the sample, the critical thinking ability test instrument, or the treatment procedure given. Therefore, the subsequent analyzes were only conducted for 14 other studies.

The analysis of the effect size in the initial results is still based on a fixed-effect model. Therefore, a sensitivity analysis is needed to obtain results that do not cause distortion, namely, selecting an appropriate estimation model. The selection of the estimation model is made through the heterogeneity test. The results of the heterogeneity test Q in Table 4 acquired a Q-value of 72.310 is greater than Q-table ($\alpha = 5\%$; df = 13), which is 23.685. Statistically, it means that there is a significant difference in the mean effect size for every study. In other words, heterogeneity is found in the effect size distribution so that the random effect model is the proper estimation model to use. This model shows that the effect sizes of each study are similar but not identical (Borenstein et al., 2009). According to Anugraheni in her study, this heterogeneity was caused by internal factors such as intelligence, interests, health, and external factors such as family conditions, school, and social environment (Anugraheni, 2018).

Furthermore, in the analysis of random-effects models for 14 studies, it was found that the combined effect size was 0.970 (high effect category). If compared to the effect size before one study was trimmed, that is 1.086; it can be seen that this difference is quite far. Thus, it shows that publication bias can significantly affect the overall effect size and the significance of the meta-analysis results. However, with an analysis of publication bias, these weaknesses can be overcome so that significantly in the analysis, it was found that the implementation of the PBL model had a high effect on junior high school students' mathematical critical thinking skills. The finding of this study is slightly different from the result of the Asror study, which found that PBL affects the critical thinking skill of students with an effect size of 0.42 (moderate effect category) (Asror, 2016). The inclusion criteria set by Asror (2016) can cause this difference; that is, the meta-analysis uses a combination of junior and senior high school study results, while this meta-analysis only uses studies at the junior high school level. Also, the finding in this study is quite different from the study result of Mustaffa et al. (2014), who found that the application of PBL at the junior secondary level was not very practical compared to conventional models because students have been accustomed to conventional model since kindergarten. This difference can arise due to differences in research subjects and external factors that the researcher cannot fully control. Besides, based on the significance test, the obtained p-value < 0.05 means that overall the implementation of the PBL model

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had a higher effect on junior high school students' critical thinking skills than the conventional learning model. Thus, it can be said that the use of the PBL model for learning mathematics in junior high school is recommended because of its positive effect on improving students' mathematical critical thinking skills.

According to Table 6, it can be noticed that the p-value in the Z test for four study characteristics is smaller than 0.05. This result shows that the implementation of the PBL model is more potent than the conventional model regarding the characteristics of the study. Examining from the characteristics of the class of study, because the study focused on the junior high school level, three study groups were obtained, as shown in Table 6. From the table, information is obtained that the effect size in studies with class VII was 1.335 (very high effect), followed by class VIII, which had an effect size of 0.925 (high effect), and class IX, which had an effect size of 0.611 (moderate effect). When referring to the effect size value, it can be said that the implementation of the PBL model is very suitable to be applied to class VII because of its very high effect on improving students' mathematical critical thinking skills. This suitable condition can be caused by the teaching material presented in class VII is material that is very suitable to be taught with the PBL model, such as sets, fractions, integers, rectangular shapes, and so on. Problems as the basis for PBL can be made easily from those materials, and the contextuality is very close to students' lives. Otherwise, at a higher level, changes in the material that are starting to become more abstract make the influence of PBL not as high as if it is applied to class VII.

Meanwhile, the Q-value obtained as a heterogeneity test is 5.697 smaller than the Q-table ($\alpha = 0.05$; $df = 2$), which is 5.991. It means that there is no significant difference in effect size among study groups based on the class of study. In other words, the magnitude of the implementation of the PBL model on mathematical critical thinking skills between study groups does not differ based on the class of study. The absence of a significant difference in effect size between research class groups based on the findings in this study indicates that the implementation of PBL is very suitable to be implemented in grades VII, VIII, and XI. The reason is that the impact will be the same to improve mathematical critical thinking skills, with a note that implementation is carried out maximally. This finding differs from the study result of Dochy et al., who found differences in effects between study groups based on the class of study (Dochy et al., 2003). Differences in findings with previous studies are caused by differences in the conditions of students who are the subject of research and other external factors. Besides, the previous research was conducted on students outside Indonesia so that existing disparities can affect research results.

Based on the year of study characteristic, researchers in the study observed conducted their research in the year range of 2013-2020 so that those studies could be made into two study groups, as in Table 6. Descriptively obtained that the effect size in the year of study 2013-2016 was 1.129 with the very high effect category, while the effect size in the year of study 2017-2020 was 0.848 with the high effect category. Thus, the effect sizes of the two groups are pretty far, and descriptively it can be said that the implementation of PBL is more effective in the year range of 2013-2016 compared to 2017-2020. This condition can be caused by the massive dissemination of PBL models carried out in line with the implementation of the 2013 Curriculum. Many researchers conducted experiments to see the impact of PBL in the early years of PBL implementation as a model recommended by the government. In addition, the influence of a model will indeed have an enormous impact when it is first implemented (Masitoh & Prasetyawan, 2019). Then, from the Q-value obtained as a heterogeneity test that is 3.752 smaller than the Q-table ($\alpha = 0.05$; $df = 1$), that is 3.841, which means that there is no significant difference in effect size between study groups based on year of study. In other words, the magnitude of the effect of the implementation of the PBL model on students' mathematical critical thinking skills between study groups does not differ based on the year of study. This finding is consistent with the study result of Gürdogan-Bayir & Bozkurt, who found that there were no differences in effects between study groups based on the year of study (Gürdogan-Bayir & Bozkurt, 2018). The absence of a significant difference in the effect of PBL implementation on students' mathematical critical thinking skills can indicate that the

implementation of this model is carried out optimally from year to year. In other words, it can be said that the high influence of PBL implementation on students' mathematical critical thinking skills is not influenced by time. This condition can be relevant to the obligation of teacher professionalism in the implementation of education written in Permendikbud Number 22 of 2016. This rule emphasizes that PBL is one of the three learning models recommended by the 2013 Curriculum so that teachers are encouraged to implement this model well every time.

Judging from the sample size characteristic, it is known that the minimum sample size of the empirical study is 21 students and the maximum is 48 students, so the categorization of the study group is made into two groups, as in Table 6. According to the table, the effect size for the sample size > 30 students was 0.926, not much different from the sample size of ≤ 30 students, namely 1,020 and both groups were equally categorized as a high effect. Therefore, the effect of the PBL model is equally suitable for small classes and large classes, namely the high effect for improving students' mathematical critical thinking skills. Meanwhile, the Q-value obtained as a heterogeneity test is 0.361 smaller than the Q-table (α = 0.05; df = 1), which is 3.841, which means that there is no significant difference in effect size between study groups based on sample size. In other words, the magnitude of the effect of the implementation of the PBL model on students' mathematical critical thinking skills between study groups does not differ referring to sample size. This finding is in line with the conclusion from previous meta-analysis research that the sample size in the PBL study group is not one of the characteristics that affect students' abilities (Demirel & Dağyar, 2016; Suparman, Juandi, et al., 2021a; Susanti et al., 2020; Paloloang et al., 2020). Also, this finding is powered by the result of Nurhasanah et al. study, which found that there was no association between effect size and sample size (Nurhasanah et al., 2017). This condition can be caused by sample selection (sampling) has been carried out appropriately and according to the procedure for both large and small samples so that the sample chosen is truly a representation of the population used by the researcher.

Meanwhile, based on the duration of treatment, the duration used in the empirical study was a minimum of 3 meetings and a maximum of 8 meetings. There is only one study that the duration of treatment requires two months, so the categorization of the study group is made into two study groups, as in Table 6. Judging from the characteristics of the duration of treatment carried out by researchers in the study, it was found that the effect size for the treatment duration of the > 4 meetings was 1.013 and categorized as high effect while for the treatment duration of 3–4 meetings was 0.592 and categorized as a moderate effect. Thus, it can be said that the treatment duration of > 4 meetings gives a more substantial impact on students' mathematical critical thinking skills rather than the treatment duration of 3–4 meetings. The high influence in the treatment group > 4 meetings shows that implementing the PBL model with sufficient time provides space for teachers to carry out learning steps very well. This situation impacts that students can independently understand the material if the time allocation required is sufficient and not in a hurry. Furthermore, the statistical Q-value obtained as a heterogeneity test is 4.474 greater than the Q-table (α = 0.05; df = 1), which is 3.841, which indicates a significant difference in effect size between study groups based on the duration of treatment. This result occurred because the implementation of the PBL model requires a reasonably long treatment duration. The ideal duration is more than four meetings until students are accustomed to the steps of the activity in PBL syntax (Arends, 2015; Hakim et al., 2014; Ilham, 2018; Juandi & Tamur, 2021; Morales-Mann & Kaitell, 2001; Sunaryo, 2014; Suparman, Juandi, et al., 2021b; Suparman, Tamur, et al., 2021; Waspadany et al., 2016; Yohannes et al., 2020; Yunita et al., 2020). Also, adequate duration of treatment and the elaboration of PBL implementation steps will make the retention period of students longer (Dochy et al., 2003). Furthermore, the problem orientation in the PBL step also requires sufficient time for individual and group investigations to achieve the desired learning outcomes (Yew & Goh, 2016). So, the duration of the treatment needs to be considered by the implementers of mathematics learning in schools so that the

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implementation of the PBL model can significantly influence the mathematical critical thinking skills of junior high school students.

Based on the discussion, it is clear that the implementation of the PBL model had a high effect on the mathematical critical thinking skills of junior high school students. Therefore, the findings in this study become relevant information for now. Therefore, researchers recommend that teachers use the PBL model to learn mathematics in schools because of its high effect on mathematical critical thinking skills. In addition, the researcher recommends that the ideal duration of PBL implementation in learning needs to be considered because it will have a more positive effect. Apart from the findings of this study, on the other hand, there are still many active learning models that also have a significant impact on students' mathematical critical thinking skills, such as the Discovery Learning model. In relevant research, it was found that the Discovery Learning model improved students' mathematical critical thinking skills compared to the comparison learning model (Dari & Ahmad, 2020; Noviyanto & Wardani, 2020). However, due to the study's limitations, the comparison of effectiveness or effect size between PBL and Discovery Learning was not discussed in this study and had the potential for further research. But, then, this study only focuses on learning mathematics, so that for other subjects, further research still needs to be done. Finally, the limitations of this study, namely the lack of statistical data from several studies and the difficulty of communicating with the authors of the primary study articles, are obstacles faced by researchers. Therefore, in the future, researchers need more attention to anticipate these limitations.

Conclusion

According to the results and findings of a meta-analysis carried out in this study, it could be inferred that the PBL model influences junior high school students' mathematical critical thinking skills. First, refer to the combined effect size with the random effect model; the implementation of the PBL model has an effect size of 0.970, which indicates that the implementation of the PBL model contributes a high effect on junior high school students' mathematical critical thinking skills. Second, it was found that the magnitude of the effect of the implementation of the PBL model on the mathematical critical thinking skill of junior high school students between study groups did not differ according to the characteristics of the class of study, year of study, and sample size. Third, it was found that there were significant differences in effect size between study groups based on the duration of treatment. Therefore, the implementation of the PBL model is powerful and effective in enhancing the junior high school students' mathematical critical thinking skills by considering the duration of treatment at the time of implementation. This finding contributes information to educators, the government, and other relevant parties regarding the effectiveness of PBL in learning activities.

However, this study is still limited to determining the effect size value of studies that contain the required statistics. There are still many other similar studies, but this study was not involved in the analysis due to the lack of statistical information. Also, the study characteristics discussed in this study are limited to the class of study, year of study, sample size and duration of treatment so that further research can analyze more study characteristics.

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References

Anugraheni, I. (2018). Meta Analisis Model Pembelajaran Problem Based Learning dalam Meningkatkan Keterampilan Berpikir Kritis di Sekolah Dasar. *Polygot*, *14*(1), 9–18. http://dx.doi.org/10.19166/pji.v14i1.789

Arends, R. I. (2015). *Learning to Teach* (10th Edition). McGraw-Hill Education.

Arifin, Hudiono, B., & Suratman, D. (2015). Pengaruh problem based learning terhadap kemampuan berpikir kritis matematis pada materi gradien di SMP. *Jurnal Pendidikan Dan Pembelajaran*, *4*(3), 1–15.

Asror, A. H. (2016). Meta-Analisis : PBL. *PRISMA Prosiding Seminar Nasional Matematika*, 508–513. https://journal.unnes.ac.id/sju/index.php/prisma/article/download/21682/10309

Beyer, B. K. (1995). *Critical Thinking*. Phi Delta Kappa Educational Foundation.

Bishop, J. (2009). *Century Skills (P21)*. Partnership For 21st Century Skills.

Borenstein, M., Hedges, L. V, Higgins, J. P. T., & Rothstein, H. R. (2009). *Introduction to Meta-Analysis*. John Wiley and Sons.

Borg, W. R., & Gall, M. D. (1983). *Educational Research: An Introduction* (5th Edition). Longman.

Changwong, K., Sukkamart, A., & Sisan, B. (2018). Critical thinking skill development: Analysis of a new learning management model for Thai high schools. *Journal of International Studies*, *11*(2), 37–48. https://doi.org/10.14254/2071-8330.2018/11-2/3

Decoster, J. (2009). Meta-Analysis Notes. In *Narrative*. Institute for Social Science Research, University of Alabama.

Demirel, M., & Dağyar, M. (2016). Effects of Problem-Based Learning on Attitude: A Meta-analysis Stud. *EURASIA Journal of Mathematics, Science & Technology Education*, *12*(8), 2115–2137. https://doi.org/10.12973/eurasia.2016.1293a

Dewey, J. (1909). *How We Think*. DC Health & Co.

Dochy, F., Segers, M., Van den Bossche, P., & Gijbels, D. (2003). Effects of problem-based learning: A meta-analysis. *Learning and Instruction*, *13*(5), 533–568. https://doi.org/10.1016/S0959-4752(02)00025-7

Facione, P. a. (2015). Critical Thinking : What It Is and Why It Counts. In *Insight assessment* (Issue ISBN 13: 978-1-891557-07-1.).

Galand, B., Frenay, M., & Raucent, B. (2012). Effectiveness of problem-based learning in engineering education: A comparative study on three levels of knowledge structure. *International Journal of Engineering Education*, *28*(4), 939–947.

Gijbels, D., Dochy, F., Van Den Bossche, P., & Segers, M. (2005). Effects of problem-based learning: A meta-analysis from the angle of assessment. *Review of Educational Research*, *75*(1), 27–61. https://doi.org/10.3102/00346543075001027

Glass, G. V, McGraw, B., & Smith, M. L. (1981). *Meta-Analysis in Social Research*. Sage Publications.

Gürdogan-Bayir, Ö., & Bozkurt, M. (2018). Effectiveness of Cooperative Learning Approaches Used in the Course of Social Studies in Turkey: a Meta-Analysis Study. *Online Submission*, *4*(10), 171–192. https://doi.org/10.5281/zenodo.1313863

Hafni, R. N., & Nurlaelah, E. (2018). Analysis the Students' Decision-Making Style in Mathematical Critical Thinking Skill. *Advanced Journal of Technical and Vocational Education*, *2*(229), 7–12. https://doi.org/10.26666/rmp.ajtve.2018.1.2

Hakim, S., Noer, S. H., & Gunowibowo, P. (2014). Penerapan Pembelajaran Berbasis Masalah untuk Meningkatkan Kemampuan Berfikir Kritis dan Disposisi Matematis. *Jurnal Pendidikan Matematika Unila*, *2*(6), 1–12.

http://journal.uinjkt.ac.id/index.php/jp3i

Herman, T. (2007). Pembelajaran Berbasis Masalah untuk Meningkatkan Kemampuan Berpikir Matematis Tingkat Tinggi Siswa Sekolah Menengah Pertama. *Educationist*, *1*(1), 3.

Ilham, H. (2018). Problem Based Learning Dengan Strategi Konflik Kognitif Meningkatkan Kemampuan Berpikir Kritis Matematis. *Eduma : Mathematics Education Learning and Teaching*, *7*(1). https://doi.org/10.24235/eduma.v7i1.2887

Islahuddin, Ilyas, M., Basir, F., & Amini, S. F. (2018). Peningkatan Kemampuan Berpikir Kritis Matematika Siswa dan Habits Of Mind (Striving For Accuracy) Melalui Pembelajaran Berbasis Masalah. *Proximal Jurnal Penelitian Matematika Dan Pendidikan Matematika*, *1*(2), 107–116.

Juandi, D., & Tamur, M. (2021). The impact of problem-based learning toward enhancing mathematical thinking: A meta-analysis study. *Journal of Engineering Science and Technology*, *16*(4), 3548–3561.

Kul, Ü., Çelik, S., & Aksu, Z. (2018). The impact of educational material use on mathematics achievement: A meta-analysis. *International Journal of Instruction*, *11*(4), 303–324. https://doi.org/10.12973/iji.2018.11420a

Lamb, S., Doecke, E., & Maire, Q. (2017). Key Skills for the 21st Century: An evidence-based review. *NSW Government*, 70.

Marlina, E., & Harahap, E. (2018). Mengembangkan Kemampuan Berpikir Kritis dan Resiliensi Matematik Melalui Pembelajaran Program Linier Berbantuan QM for Windows. *Jurnal Matematika Unisba,* 17(2).

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

Masitoh, L. F., & Prasetyawan, E. (2019). The effectiveness of scientific approach with open-ended problem-based learning worksheet viewed from learning achievement, creative thinking ability, interest, and mathematics self-efficacy. *Daya Matematis: Jurnal Inovasi Pendidikan Matematika*, 7(3), 292-308.

Miterianifa, Trisnayanti, Y., Khoiri, A., & Ayu, H. D. (2019). Meta-analysis: The effect of problem-based learning on students' critical thinking skills. *AIP Conference Proceedings*, *2194*(December). https://doi.org/10.1063/1.5139796

Morales-Mann, E. T., & Kaitell, C. A. (2001). Problem-based learning in a new Canadian curriculum. *Journal of Advanced Nursing*, *33*(1), 13–19. https://doi.org/10.1046/j.1365-2648.2001.01633.x

Mustaffa, N., Ismail, Z., Tasir, Z., Nihra, M., Bin, H., & Said, M. (2014). Problem-Based Learning (PBL) in Mathematics : A Meta Analysis. *International Education Postgraduate Seminar*, *November 2014*, 301.

Noer, S. H., & Gunowibowo, P. (2018). Efektivitas Problem Based Learning Ditinjau Dari Kemampuan Berpikir Kritis Dan Representasi Matematis. *Jurnal Penelitian Dan Pembelajaran Matematika*, *11*(2). https://doi.org/10.30870/jppm.v11i2.3751

Nurafiah, F., Nurlaelah, E., & Sispiyati, R. (2013). Perbandingan Peningkatan Kemampuan Berpikir Kritis Siswa SMP Antara yang Memperoleh Pembelajaran Means-Ends Analysis (MEA) dan Problem Based Learning (PBL). *Jurnal Pengajaran MIPA*, *18*(1), 1–8. https://doi.org/10.18269/jpmipa.v18i1.205

Nurhasanah, Sutrisno, L., & Silitonga, H. T. M. (2017). *Pengaruh Problem Based Learning Pada Hasil Belajar Fisika: Sebuah Meta-Analisis Artikel Jurnal Online Indonesia*. *6*(3), 1–12.

Paloloang, M. F. B., Juandi, D., Tamur, M., Paloloang, B., & Adem, A. M. G. (2020). Meta Analisis: Pengaruh Problem-Based Learning Terhadap Kemampuan Literasi Matematis Siswa Di Indonesia Tujuh Tahun Terakhir. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *9*(4), 851–864. https://doi.org/10.24127/ajpm.v9i4.3049

Putri, S. A., & Fauzan, A. (2019). Pengaruh Model Problem Based Learning Terhadap Kemampuan Berpikir Kritis Matematis Peserta Didik di Kelas VIII SMP Negeri 2 Padang Panjang. *Jurnal Edukasi Dan Penelitian Matematika UNP*, *8*(2).

Radin, D. I. (2009). *The conscious universe: The scientific truth of psychic phenomena*. *October*, 432.

Roekel, D. Van. (2016). Preparing 21st Century Students for a Global Society an Educator's Guide to the "Four Cs" able of Contents. *National Education Association*, *Great Public Schools for Every Student*, 1–37.

Sari, A. D., Rahim, U., & Arapu, L. (2014). Perbedaan Peningkatan Kemampuan Berpikir Kritis Matematik Siswa Kelas VIII SMP Negeri 5 Kendari yang Diajar Model Pembelajaran Problem-Based Learning (PBL) dan Konvensional. *Jurnal Penelitian Pendidikan Matematika*, *2*(2), 19–36. https://doi.org/http://dx.doi.org/10.36709/jppm.v2i2.3092

Sari, Y., Surya, E., & Asmin. (2019). *The Increasing of Student's Mathematics Critical Thinking Ability Through Problem Based Learning*. *384*(AISTEEL 2019), 563–566. https://doi.org/10.2991/aisteel-19.2019.126

Schlegel, S. (2011). Mind in the Making: The Seven Essential Life Skills Every Child Needs. In *Journal of Developmental & Behavioral Pediatrics* (Vol. 32, Issue 5, p. 401). https://doi.org/10.1097/dbp.0b013e31821f8d89

Sirait, D. M. B. (2019). Pengaruh Model Pembelajaran Berbasis Kritis Matematis Siswa Kelas VIII SMP. *Cartesius: Jurnal Pendidikan Matematika*, *2*(1), 75–89. https://doi.org/http://dx.doi.org/10.1234/cartesius.v2i1.488

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

Sunaryo, Y. (2014). Model Pembelajaran Berbasis Masalah untuk Meningkatkan Kemampuan Berpikir Kritis dan Kreatif Matematik Siswa SMA di Kota Tasikmalaya. *Jurnal Pendidikan Dan Keguruan*, *1*(2), 5.

Suparman, Juandi, D., & Tamur, M. (2021a). Problem-Based Learning for Mathematical Critical Thinking Skills : A Meta-Analysis. *Journal of Hunan University (Natural Sciences）*, *48*(2), 133–144.

Suparman, Juandi, D., & Tamur, M. (2021b). Does problem-based learning enhance students' higher order thinking skills in mathematics learning? A systematic review and meta-analysis. *The 4th International Conference on Big Data and Education*, 44–51. https://doi.org/https://doi.org/10.1145/3451400.3451408

Suparman, S., Tamur, M., Yunita, Y., Wijaya, T. T., & Syaharuddin, S. (2021). Using Problem-Based Learning to Enhance Mathematical Abilities of Primary School Students: A Systematic Review and Meta-Analysis. *JTAM (Jurnal Teori Dan Aplikasi Matematika)*, *5*(1), 144. https://doi.org/10.31764/jtam.v5i1.3806

Susanti, A. E., & Suwu, S. E. (2016). Penerapan Pembelajaran Berbasis Masalah untuk Meningkatkan Ketrampilan Berpikir Kritis Siswa Kelas IX dalam Pelajaran Ekonomi [Problem-Based Learning Implementation to Increase Grade IX Students' Critical Thinking Skill in Learning Economics]. *Polyglot: Jurnal Ilmiah*, *12*(1), 66–81. https://doi.org/10.19166/pji.v12i1.383

Susanti, N., Juandi, D., & Tamur, M. (2020). The Effect of Problem-Based Learning (PBL) Model On Mathematical Communication Skills of Junior High School Students – A Meta-Analysis Study. *JTAM (Jurnal Teori Dan Aplikasi Matematika)*, *4*(2), 145–154. https://doi.org/10.31764/jtam.v4i2.2481

Tamur, M., Juandi, D., & Adem, A. M. G. (2020). Realistic Mathematics Education in Indonesia and Recommendations for Future Implementation : A Meta-Analysis Study. *Jurnal Teori Dan Aplikasi Matematika*, *4*(1), 17–27. https://doi.org/10.31764/jtam.v4i1.1786

Turgut, S., & Turgut, I. G. (2018). The effects of cooperative learning on mathematics achievement in Turkey: A meta-analysis study. *International Journal of Instruction*, *11*(3), 663–680. https://doi.org/10.12973/IJI.2018.11345A

UNESCO. (2011). *UNESCO and Education*. UNESCO.

http://journal.uinjkt.ac.id/index.php/jp3i

Uribe-Enciso, O. L., Uribe-Enciso, D. S., & Vargas-Daza, M. D. P. (2017). Pensamiento crítico y su importancia en la educación: algunas reflexiones. *Expresiones, Revista Estudiantil de Investigación*, *19*(34), 78–88. https://doi.org/10.16925/ra.v19i34.2144

Walker, A., & Leary, H. (2009). A Problem Based Learning Meta Analysis: Differences Across Problem Types, Implementation Types, Disciplines, and Assessment Levels. *Interdisciplinary Journal of Problem-Based Learning*, *3*(1), 10–43. https://doi.org/10.7771/1541-5015.1061

Warmi, A. (2017). Penerapan Pembelajaran Berbasis Masalah Dalam Meningkatkan Kemampuan Berpikir Kritis Matematis Siswa. *Utile Jurnal Kependidikan*, *3*(2), 156–161.

Waspadany, E., Asnawati, R., & Noer, S. H. (2016). Penerapan Pembelajaran Berbasis Masalah Untuk Meningkatkan Kemampuan Berpikir Kritis dan Self Confidence. *Jurnal Pendidikan Matematika*, *4*(3).

Widyatiningtyas, R., Kusumah, Y. S., Sumarmo, U., & Sabandar, J. (2015). The Impact of Problem-Based Learning Approach to Senior High School Students' Mathematics Critical Thinking Ability. *Indonesian Mathematical Society Journal on Mathematics Education*, 6(2), 30-38.

Yanti, O. F., & Prahmana, R. C. I. (2017). Model Problem Based Learning, Guided Inquiry, dan Kemampuan Berpikir Kritis Matematis. *Jurnal Review Pembelajaran Matematika*, *2*(2), 120–130. https://doi.org/10.15642/jrpm.2017.2.2.120-130

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/10.1016/j.hpe.2016.01.004

Yohannes, Y., Juandi, D., & Diana, N. (2020, October). The Evaluation of Problem-Based Learning Model Towards High School Students' Critical Thinking Skills: A Meta-Analysis Study in Indonesia. *In 2020 12th International Conference on Education Technology and Computers* (pp. 199-204).

Yunita, Y., Juandi, D., Tamur, M., Adem, A. M. G., & Pereira, J. (2020). A meta-analysis of the effects of problem-based learning on students' creative thinking in mathematics. *Beta: Jurnal Tadris Matematika*, *13*(2), 104–116. https://doi.org/10.20414/betajtm.v13i2.380

Yuwono, M. R., Udiyono, U., Maarif, D. H., & Sulistiana, S. (2019). Students' Critical Thinking Profile To Solve The Problem Of Analytical Geometry Viewed From Gender. Al-Jabar: J*urnal Pendidikan Matematika*, 10(1), 37-46.

Zamzam, K. F. (2016). Pendekatan Problem Based untuk Learning Mengembangkan Kemampuan Berfikir Kritis Mahasiswa. *Pedagogia*, *5*(2), 279–286.