World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

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Meta-analysis: The effect of problem-based learning on higher-order thinking skills of Indonesian students

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World Journal of Advanced Research and Reviews, 2024, 22(01), 312–321

Publication history: Received on 24 February 2024; revised on 02 April 2024; accepted on 05 April 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.22.1.1074

Abstract

Higher order thinking skills are one of the competencies developed in learning, especially in mathematics. One of the effective learning models to improve higher order thinking skills is Problem-Based Learning (PBL). In this study, a meta-analysis method was used, which involved analyzing various articles that had been collected. Search procedures through Google Scholar and Garuda Portal and found 99 articles that discuss the effect of PBL implementation in Indonesia on students' higher order thinking skills. Of these 99 articles, only 11 articles met the inclusion criteria and were then analyzed using the meta-analysis method. This meta-analysis method provides results in the form of a combined effect size that describes the extent of the influence of PBL implementation on students' higher order thinking skills. Based on the interpretation of the combined effect size, it can be concluded that overall, the application of PBL has a moderate effect on students' higher order thinking skills. In other words, PBL has a positive impact in improving students' ability to think critically, analytically, creatively, and think reflectively. In addition, this study also considered study characteristics, such as education level and year of study. The statistical analysis showed the effect of PBL implementation in improving students' ability to think critically, analytically, creatively, and reflectively.

Keywords: Educational Research; Effect; Higher-Order Thinking Skills; Meta-Analysis; Problem-Based Learning (PBL)

1. Introduction

In 21st century education, the goal of learning is to encourage students to become active learners, where they can search, discover, construct, process and use their knowledge independently. This aims to create meaningful and relevant learning for students. In Indonesia, the education system has adopted this series of active student actions through the implementation of the 2013 Curriculum with a scientific approach. The scientific approach to learning involves the 5M procedures, namely observing, asking, trying, reasoning and communicating. In this context, students are encouraged to observe the surrounding environment, ask questions about phenomena they encounter, try to explore and test hypotheses, carry out reasoning and problem-solving processes, and communicate and collaborate with classmates in conveying the results of their thoughts. With this approach, learning does not only focus on solving predetermined problems, but also encourages students to formulate problems that are relevant to the context of everyday life. The main aim is to arouse students' motivation to seek information from various existing sources, through observation or direct observation, so that they can develop critical and creative thinking skills. In a scientific approach, students are not only passive recipients of information, but also become main actors in the learning process. They are encouraged to develop higher-order thinking skills, such as connecting the knowledge they have with real situations, identifying problems that need to be solved, and formulating effective problem-solving strategies. Through this approach, it is hoped that students can develop a deeper understanding and acquire relevant skills to face challenges in

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the real world. The application of a scientific approach in learning aims to create students who are active, critical and creative in facing the changes and complexity of today's world. By actively involving students in the learning process, it is hoped that they can develop independent thinking abilities, social skills and leadership needed in their future lives.

To face the increasingly complex challenges and demands of life in the 21st century, education has a very important role in providing human resources (Ramadhanti et al., 2022). Therefore, a person must master various abilities and skills, including the ability to think. There are two types of thinking abilities, namely lower-order thinking skills (LOTS) and higher-order thinking skills (HOTS) (Ramadhanti et al., 2022). HOTS is a capability that must be possessed in the 21st century (Wijaya & Astuti, 2022; Zulfah et al., 2022). One aspect of HOTS is students' critical and creative mathematical thinking abilities, mathematical problem solving, and mathematical reasoning (Ramadhanti et al., 2022; Zulfah et al., 2022). HOTS is more than just the ability to remember, know, or repeat, but rather problem solving, creative thinking, argumentativeness, and reasoning decision making. Based on Bloom's taxonomy, indicators that can be used to measure HOTS are: analyzing, evaluating, and creating (Ramadhanti et al., 2022; Zulfah et al., 2022). HOTS is the ability to retrieve new information from related information in memory and then rearrange and expand the information to find alternative answers in making decisions, innovating, and being able to create something (Sanuaka et al., 2022). By using HOTS in learning, the information obtained will be documented longer in memory compared to using lower-order thinking skills. The growth of HOTS in learning is characterized by: (1) cooperation or collaboration between teachers, students, and across sciences, (2) encouraging curiosity, exploration and investigation, (3) learning relies on students, (4) failure is seen as an opportunity learning, (5) recognition of effort, not only achievement, and (6) learning contextually in real life (Zulfah et al., 2022).

There are facts that show that students' higher-order thinking skills (HOTS) in Indonesia are still relatively low. This can be seen from the results of international studies such as the International Mathematics and Science Study (TIMSS) and the Program for International Student Assessment (PISA), which show that the achievements of Indonesian students are not yet satisfactory (Ramadhanti et al., 2022). Because of this, it is necessary to apply an appropriate learning model that can help students improve their HOTS abilities. By implementing a synchronous learning model, students can be facilitated to develop higher order thinking skills. This learning model must allow students to interact and place students as the center of learning. In this model, the use of problems that are unstructured and have many solutions can be an effective way to stimulate students to get used to solving problems that require HOTS abilities. In this context, students are given the opportunity to think critically, analyze, find solutions, and collaborate with fellow students in solving complex problems. By focusing on unstructured problems, students are faced with situations where they must apply various problem-solving strategies, carry out creative thinking, and make the right decisions. By implementing this learning model, it is hoped that students will become accustomed to and trained in facing challenges that require high-level thinking abilities. By gaining experience in working on questions classified as HOTS, students will improve their abilities in solving problems, formulating arguments, thinking critically, and producing creative solutions.

In conclusion, it is necessary to apply appropriate and appropriate learning models to help Indonesian students improve their HOTS abilities. A learning model that emphasizes the role of students as the center of learning, uses problems that are unstructured and have many solutions, can be an effective way to trigger students to become accustomed and skilled in working on problems that require HOTS abilities. In this way, it is hoped that students can develop the high-level thinking skills needed to face the demands of today's world. Among the learning models that can be applied to increase HOTS in students is problem-based learning (PBL) (Pia et al., 2021; Sanuaka et al., 2022; Wijaya & Astuti, 2022). HOTS can be trained to students through several learning models, including PBL. PBL is a problem-based learning model and can be chosen by mathematics teachers as the best solution to develop students' low problem solving, reasoning, critical thinking and creative abilities (Ramadhanti et al., 2022; Ramadhany & Prihatnani, 2020). PBL requires a thinking process to find relationships between principles and concepts obtained from learning to solve problems. So that students will be trained to think and get used to solving problems, especially those based on HOTS during the problem-solving process, besides that it can increase self-confidence and curiosity. PBL can explore students' potential, build a learning process that is full of meaning for students because it relies on students where the teacher acts as a facilitator (Ramadhanti et al., 2022). Thus, PBL is a good technique for better understanding lesson content, increasing learning activities, and transferring the knowledge received by students to be able to understand problems in real life (Ramadhany & Prihatnani, 2020).

Many meta-analysis studies have been conducted that discuss the influence of Problem-Based Learning (PBL) on students' higher-level thinking abilities. Some of this research focuses on the influence of PBL on critical thinking abilities (Anugraheni, 2018) and creative thinking abilities (Yunita et al., 2020). Seeing the results of this research, the author feels it is necessary to conduct meta-analysis research that specifically discusses the influence of PBL on students' higher order thinking abilities (HOTS). Therefore, the aim of this research is to investigate the effect of PBL on

students' higher order thinking abilities (HOTS), by comparing it with conventional learning models. This research will also consider the characteristics of educational level and year of research as factors that can influence the influence of PBL. Thus, it is hoped that the research results can provide accurate and useful information for teachers regarding the application of PBL in learning. Through this meta-analysis research, the author will collect and analyze relevant articles that have been published previously. The article collection process is carried out through sources such as Google Scholar and the Garuda Portal. After the article collection is complete, the author will carry out a meta-analysis method to evaluate the extent of the influence of implementing PBL on higher order thinking abilities.

In this research, the author will select articles that meet the predetermined inclusion criteria. These articles will be analyzed using the meta-analysis method, which is a statistical approach used to combine the results of research that has been conducted previously. From the results of this interpretation and meta-analysis, the author will produce a combined effect size that describes the influence of implementing PBL on overall higher order thinking abilities. Apart from that, the author will also look at the characteristics of the studies contained in the articles that have been collected, such as educational level and year of research. By using statistical analysis, the author will evaluate whether the effect of implementing PBL in improving students' higher-order thinking abilities is influenced by these factors. By conducting this comprehensive meta-analysis research, it is hoped that the author can provide clear and valuable information about the influence of PBL on students' higher-order thinking abilities. It is hoped that the results of this research can provide useful guidance for teachers in considering and implementing PBL in learning, as well as providing a better understanding of the importance of developing higher thinking skills in education.

2. Material and methods

This research uses a meta-analysis method by reviewing articles in national journals. Meta analysis is a statistical method used to combine, analyze and synthesize several studies systematically, with the aim of obtaining the latest findings and conclusions that can be drawn from the research results. Borenstein (2009) explains the stages in meta-analysis, namely determining the inclusion criteria for the studies to be analyzed, procedures for collecting empirical data, coding research variables, and the statistical techniques used (Rohmatulloh et al., 2022). Primary research related to the PBL model and students' higher order thinking abilities is the focus of this research. In this research, a review was carried out of articles in primary studies that met the predetermined inclusion criteria, namely:

1. The range of article publication years is from 2018 to 2023.
2. In this research, articles that have conducted research studies in Indonesia and have been published in journals listed in the SINTA index are the focus of attention.
3. Articles with quasi-experimental research methods and randomized control group pretest-posttest design, randomized control group posttest only design, nonequivalent qroup pretest-posttest design, and nonequivalent qroup design posttest only.
4. In this research, the articles that are the main focus involve student populations from primary (SD), secondary (SMP), and upper (SMA) education levels in Indonesia.
5. In this research, the articles that are the main focus are those that present statistical data on primary studies, such as sample size, mean and standard deviation.

Article searches were carried out on databases such as Google Scholar and the Garuda Portal using keywords such as "Problem-Based Learning, HOTS", "PBL, Higher Order Thinking Abilities", "Problem Based Learning, Higher Order Thinking Abilities", and "Level Thinking Abilities Tall". Based on searches carried out in the publication year range 2018-2023, 99 relevant articles were found. Then, articles were selected based on the predetermined inclusion criteria, and finally 11 articles were selected that met these criteria. These articles cover studies at primary (SD), secondary (SMP/MTs), and upper (SMA/equivalent) education levels.

The next process is carrying out study coding. The instrument used in this process is a coding protocol which can be a coding form on paper or a computer, as well as a manual guide that explains how to code each item based on data in the primary study (Apriatni et al., 2022). Coding this study includes information such as study code, author, year of publication, mean, standard deviation, and number of samples in the experimental group and control group, as well as educational level and year of research. After the coding process is complete, the effect size is calculated using the standardized mean difference known as Hedges's g (Rohmatulloh et al., 2022). Interpretation of research results refers to the guidelines put forward by Cohen (Parno et al., 2020). The formula for calculating Hedges's g is as follows:

$$Hedges'g = \frac{\bar{X}_1 - \bar{X}_2}{SD^*_{pooled}} \quad (1)$$

Information:

$\bar{X}_{1-}\ \bar{X}_{2}$= difference in means.

SD*pooled = pooled and weighted standard deviation.

Meanwhile, the interpretation of the effect size is shown in Table 1 below:

Table 1 Interpretation of effect Sizes

ICE	ES Interpretation
0 ≤ ES ≤ 0.20	Weak effect
0.20 < ES ≤ 0.50	Simple effect
0.50 < ES ≤ 1.00	Medium effect
ES > 1.00	Strong effect

The next process involves a homogeneity test to determine the analysis model to be used, using the p-value (Rohmatulloh et al., 2022). If the p-value < 0.05, then the data is heterogeneous, and the analysis model used is a random effects model. Meanwhile, if the p-value is > 0.05, then the data is homogeneous, and the analysis model used is a fixed effects model (Rohmatulloh et al., 2022). To prevent inaccurate representation in findings, it is necessary to check for publication bias.

Published studies are more likely to be included in a meta-analysis than unpublished studies, which may raise concerns that meta analyzes may produce effect sizes that are too large (Borenstein et al., 2009). Methods used to detect and overcome publication bias, for example, are funnel plots and Rosenthal's Fail-Safe N (FSN) (Rohmatulloh et al., 2022). An initial approach to detecting publication bias is through the use of funnel plots. If a study's effect size distribution was asymmetrical or not completely symmetrical, then Rosenthal's FSN was used to help determine the presence of publication bias. When value $\frac{FSN}{5k+10}$> 1, where k is the number of studies in the meta-analysis, studies held against publication bias. If there is no indication of publication bias, the analysis process can continue. Through the analysis model, the author can test the null hypothesis (H0). If the p-value < 0.05, then H0 will be accepted. If the analysis model uses random effects which takes into account different research characteristics, the author can analyze the research characteristics and interpret the results of the analysis (Borenstein et al., 2009).

3. Results and discussion

This research aims to determine how much influence the use of the PBL model has on students' higher-order thinking abilities by combining the results of several studies. In this research, a series of studies will be carried out to obtain information regarding the impact of implementing PBL on students' higher order thinking abilities (HOTS). The following is a list of studies that will be carried out in this research.

The meta-analysis research that will be carried out in this context will analyze a total of 11 relevant and selected studies. These studies will be selected based on predetermined inclusion criteria, taking into account factors such as relevance to the research topic, accuracy of the data presented, and journal indexation in the SINTA database. In the study selection process, the author will pay attention to the SINTA index which covers categories 1 to 5. This category shows the level of prestige and quality of the journals that publish these studies. By considering the SINTA index category, the author will select studies published in journals indexed in that category. This will ensure that the studies used in the research have a high level of accuracy, reliability and quality. Apart from that, this meta-analysis research will involve several studies as research subjects. This means, the studies selected in this research will cover various learning areas, such as mathematics, science, language, and so on. By considering variations in learning areas, this research will provide a more comprehensive picture of the influence of PBL on higher-order thinking abilities in various learning contexts. In analyzing the selected studies, the author will conduct a thorough review of each article. The author will carefully pay attention to and evaluate the data presented, the research methodology used, the samples used, as well as the findings and results obtained in each study. This will ensure that the meta-analysis research carried out is based on valid and reliable data. By involving 11 selected and relevant studies, this meta-analysis research is expected to provide a clearer

and deeper understanding of the influence of PBL on students' higher-order thinking abilities. In different learning contexts, this research will provide rich and useful information for educational practitioners, teachers and decision makers in the field of education.

Table 2 Studies Used in Meta-analysis

Study Code	Study Title	Journal Name	Journal Index
Study 1	Thinking Hots in Social Sciences Problem Based Learning Methods	IPS Research and Education Journal (Jppi)	Sinta 4
Study 2	The Effect of Problem Based Learning on Collaboration Skills and Higher Order Thinking	Bioeducated Journal	Sinta 4
Study 3	The Effectiveness of PBL-Based HOTS in English Learning	Innovative Journal of Curriculum and Educational Technology	Sinta 3
Study 4	The Influence of the Problem Based Learning Model on Higher Level Thinking Abilities and Learning Outcomes of Class V Elementary School Students	Education Journal: Theory, Research, and Development	Sinta 2
Study 5	The Influence of the Problem Based-Learning Model with a Flipped Classroom on Creative Thinking Ability	Journal of Education	Sinta 5
Study 6	The Effect of Problem-Based Learning Integrated Local Wisdom on Student HOTS and Scientific Attitude	Journal of Science Education Research (JPPIPA)	Sinta 2
Study 7	The Effect of Implementing Blended Learning in the PBL Model on Creative Thinking Ability during the Covid-19 Pandemic	Equilibrium: Journal of Educational and Economic Research	Sinta 4
Study 8	The Effect of Implementation of Inquiry-Based Learning with Socio-Scientific Issues on Students' Higher-Order Thinking Skills	Journal Of Science Learning	Sinta 2
Study 9	The Effect of Problem-Based Learning Assisted by LKPD on Higher Level Thinking Abilities in Class VII	Journal of Mathematics Education and Science	Sinta 4
Study 10	The Influence of the Problem-Based Learning (PBL) Model on the Ability to Solve HOTS Type Mathematical Problems and Learning Motivation of MA Amanatul Ummah Mojokerto Students	Vehicle: Tridharma of Higher Education	Sinta 5
Study 11	The Influence of the Problem-Based Learning Model Assisted by Interactive Multimedia and Cooperative Learning Type STAD on Mathematics Learning on HOTS Ability (Experimental Study of Class V Elementary School Students in Sukasari District)	Pendas: Scientific Journal of Basic Education	Sinta 4

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

Based on the data in Table 3, each study has variations in effect size, where there are 11 studies with effect sizes ranging from 0.0360 to 1.7040. In interpreting this effect size using Cohen's classification, there is information that 3 studies show a strong effect size, or it can be said that the application of PBL in these 3 studies has a strong influence on student HOTS. Furthermore, there were 5 studies with a medium effect size, which means that the implementation of PBL in these 5 studies had a moderate effect on students' HOTS. There was also 1 study with a modest effect size, indicating that the implementation of PBL in this study had a modest effect on student HOTS. Finally, there were 2 studies with weak effect sizes, indicating that the implementation of PBL in these studies had a weak influence on students' HOTS.

Table 3 Effect Sizes, Interpretation of Effect Sizes, Standard Errors, and Confidence Intervals for Each Study

Study Code	Author, Year of Publication	Effect Size	Interpretation of Effect Sizes	SE	Confidence Interval	
					Lower limit	Upper limit
Study 1	(Triasningsih, 2020)	0.4230	Simple	0.2611	-0.0891	0.9351
Study 2	(Ilmiyatni et al., 2019)	1.1280	Strong	0.2785	0.5807	1.6753
Study 3	(Simanungkalit et al., 2019)	0.1517	Weak	0.2394	-0.3175	0.6209
Study 4	(Puspitasari et al., 2020)	0.5620	Currently	0.3011	-0.0288	1.1528
Study 5	(Damayanti et al., 2020)	0.5916	Currently	0.2739	0.0543	1.1289
Study 6	(Hikmawati et al., 2021)	0.9046	Currently	0.2947	0.3259	1.4833
Study 7	(Koyimah et al., 2021)	0.7023	Currently	0.3010	0.1116	1.2931
Study 8	(Qamariyah et al., 2021)	1.7040	Strong	0.2565	1,1999	2.2082
Study 9	(Alya Kamila et al., 2022)	1.0478	Strong	0.2670	0.5233	1.5723
Study 10	(Ardianik & Kusmiyati, 2023)	0.6306	Currently	0.2679	0.1068	1.1544
Study 11	(Rahmanudin et al., 2023)	0.0360	Weak	0.3044	-0.5606	0.6326

Table 4 provides information about the homogeneity tests of all primary studies used to determine the pooled effect size. The author must create an estimation model by conducting homogeneity tests on all main studies.

Table 4 Heterogeneity of Effect Size Distributions

Heterogeneity				
Chi-Squared	Df	P-Value	I-Squared	σ2
31.25	10	< 0.01	68 %	0.1541

Based on the information provided, in Table 4 there is a p-value of less than 0.05, which indicates that the distribution of effect sizes from meta-analyzed primary studies is heterogeneous in nature. Therefore, the estimation model used to determine the combined effect size is a random effects model. Next, publication bias was identified using a funnel plot. The funnel plot graph is shown below.

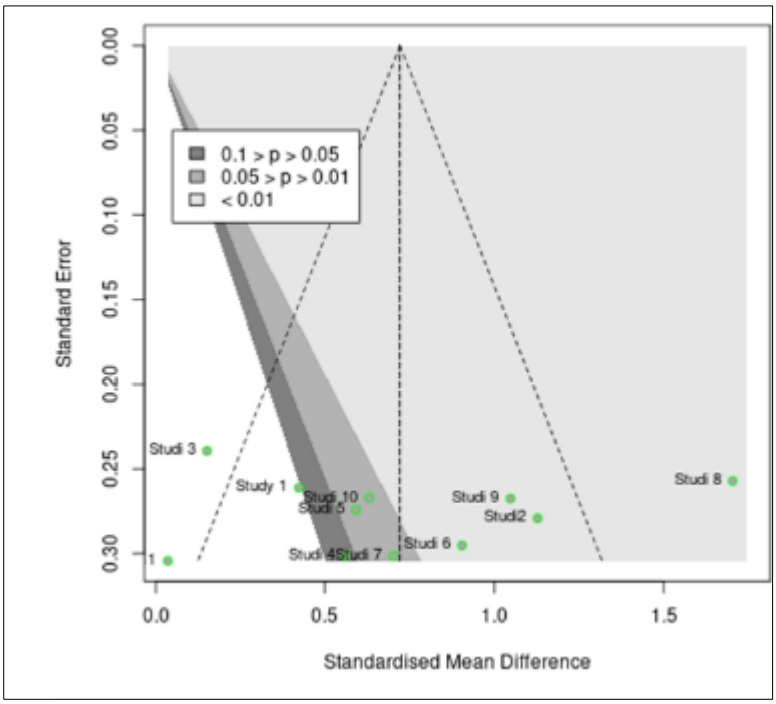

Figure 1 Funnel Plots

Based on Figure 1, it can be observed that the effect size distribution of the studies has an asymmetrical shape. In this case, the author identified publication bias by using a Fail-Safe N (FSN) value of 295 from the total observed studies (k) of 11, which means that 295 unpublished research results with insignificant results were needed, resulting in pooled ES = 0. By using the formula, it can be concluded that this meta-analysis has sufficient tolerance for publication bias $\frac{FSN}{5k+10} = \frac{295}{5(11)+10} = \frac{295}{65} = 4{,}52 > 1$ (Tamur et al., 2020).

Next, Table 5 displays the meta-analysis results of primary studies using fixed-effects and random-effects models.

Table 5 Results Meta-Analysis Based on Estimation Models

Model	**n**	**Effect Size and 95% Confidence Interval**				***Test of Nulls*(2-Tail)**	
		Effect Size	SE	Lower limit	Upper limit	*Z-value*	*P-value*
Fixed effects model	11	0.7218	0.3249	0.5593	0.8842	8.71	< 0.0001
Random effects model	11	0.7194	0.6377	0.4006	1.0383	5.03	0.0005

Based on the information provided, because the homogeneity test showed that the distribution of primary study effect sizes was heterogeneous, the analysis used a random effects model. In Table 5, there is a p-value in the Z test of 0.0005. Because the p-value < 0.05, it can be concluded overall that the use of PBL has a significant influence on students' higher-order thinking abilities than conventional models. Furthermore, from this study it was found that the combined effect size was 0.7194, which according to Cohen's classification was categorized as a medium effect size. In conclusion, the overall implementation of PBL has a moderate influence on student HOTS. In addition, the combined effect of 0.7194 means that the average HOTS of students increased by 68% compared to the control group (Rohmatulloh et al., 2022). Due to heterogeneity in the distribution of primary study effect sizes, it is recommended to conduct analyzes of study characteristics that may contribute to heterogeneity in student HOTS. The results of the meta-analysis of these characteristics can be found in Table 6.

Table 6 Results Meta-analysis of Each Study Characteristic

Study Characteristics	Category	n	Hedge'sg		95%CI	
				P-value	Lower limit	Upper limit
Educational level	elementary school	2	0.30	0.22	-3.04	3.64
	junior high school	3	0.78	0.22	-0.05	1.61
	high school	6	0.82	< 0.01	0.25	1.38
Year of research	2019	3	0.55	0.03	-0.69	1.80
	2020	2	0.58	0.94	0.39	0.77
	2021	3	1.12	0.02	-0.21	2.45
	2022	1	1.05	-	0.52	1.57
	2023	2	0.35	0.14	-3.42	4.12

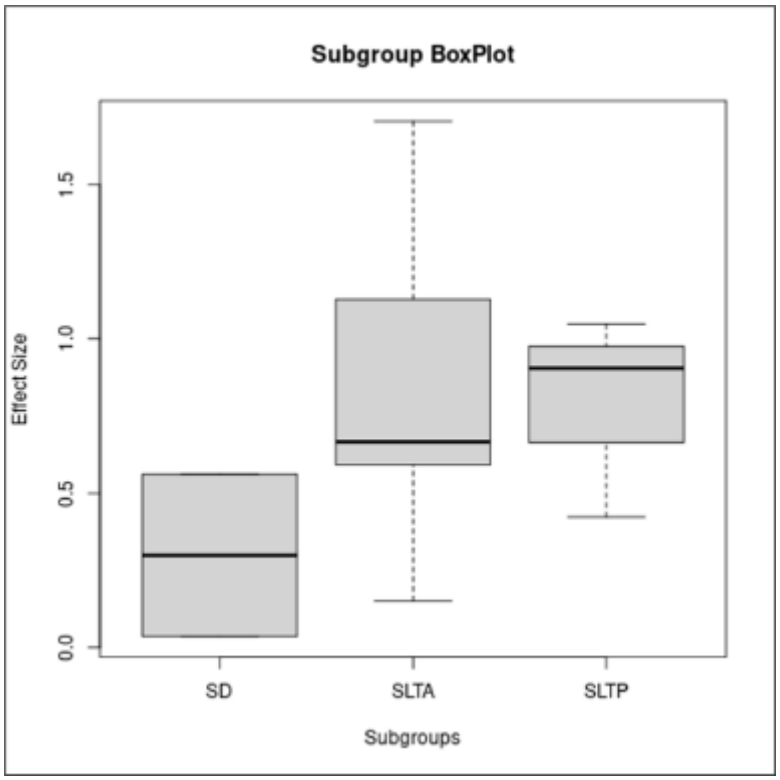

Figure 2 BoxPlot

Based on Table 6, in the analysis of study characteristics of educational levels, it was found that the effect in the senior high school category had the highest effect size value compared to the high school and elementary school categories. Apart from that, it was also found that the total p-value for the high school category in the heterogeneity section was < 0.01. Thus, the p-value < 0.05, this means that the distribution of effects across categories in the characteristics of this study is heterogeneous. For more details, see Figure 2 above.

Based on the characteristics of studies conducted in certain years, it was found that the lowest study effect size occurred in the 2023 period and was categorized as a modest study effect, while a high study effect size occurred in the 2021 period and was categorized as a strong study effect. There are significant differences in the effect of implementing PBL on students' higher-order thinking abilities based on the year of research. The research results concluded that the application of PBL to improve students' higher-order thinking abilities was influenced by the year of research. Low mathematical abilities in students are caused by the use of inappropriate learning methods, and to improve problem solving, critical thinking and reasoning skills, teachers need to abandon conventional methods. Therefore, one strategy

that is considered effective in improving problem solving, critical thinking and reasoning abilities is to use the Problem-Based Learning (PBL) model as mentioned in (Khaeroh et al., 2020). Thus, these studies show that the application of PBL has benefits in increasing students' motivation, understanding of concepts, critical thinking skills and mathematical communication skills.

4. Conclusion

Based on a meta-analysis of 11 studies conducted, it was found that the combined effect size of the primary studies was 0.7194, which is included in the medium effect category according to Cohen's classification. Thus, the general conclusion that can be drawn is that the use of PBL has a moderate impact on students' higher order thinking abilities (HOTS) compared to traditional learning models. Traditional learning is generally dominated by the role of the teacher as the center of learning, while students play more of a role as objects in the learning process. Apart from that, it was also found that the application of PBL to improve students' higher order thinking abilities (HOTS) could be influenced by their level of education and year of study. These findings provide an important contribution for educators in using PBL as an alternative learning method that can help improve students' higher order thinking abilities (HOTS). Thus, the results of this meta-analysis provide a deeper understanding of the benefits and influence of PBL in the context of improving students' higher order thinking abilities (HOTS), as well as providing recommendations for educators to consider using PBL as an effective learning model.

Compliance with ethical standards

Disclosure of Conflict of interest

No conflict of interest to be disclosed.

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