Journal of Didactic Studies

Published by: Indonesian DDR Development Centre
Directorate of Innovation and University Center of Excellence, Universitas Pendidikan Indonesia
Journal homepage: https://ejournal.upi.edu/index.php/jds

The effects of problem-based learning on mathematical proficiency: A combined bibliometric analysis and meta-analysis review

D. Fardian[1], D. Dasari[1]*

[1]Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia
Correspondence: E-mail: dadan.dasari@upi.edu

ABSTRACTS

The research goals are investigating the impacts of applying Problem-Based Learning (PBL) on mathematical proficiency. 23 primary research papers that met the inclusion assumptions were investigated in this study using a meta-analysis methodology. The Scopus database and UPI repository were used to identify empirical data. Additionally, the characteristics of publication year, strands of mathematical proficiency, geographic level, education level, and class level are examined in this study. The Comprehensive Meta-Analysis (CMA) application was employed to carry out the statistical computations, and the random effects model was followed throughout the calculation process. As a consequence, the overall of effect size is 0.77. Compared to traditional learning, the results showed that PBL implementation significantly improved students' mathematical proficiency. The analysis of moderator variables suggests that PBL works best when it is applied to strengthen the conceptual understanding and procedural fluency strands of mathematical proficiency. This discovery contributes valuable insights for the future implementation of PBL. Thus, these results recommend that collaborative studies among countries regarding the impact of Project-Based Learning will be crucial in the future to generate more comprehensive and inclusive results.

© 2023 Universitas Pendidikan Indonesia

ARTICLE INFO

Article History:
Received 25 Oct 2023
Revised 16 Nov 2023
Accepted 18 Des 2023
Available online 30 Des 2023

Keyword:
Problem-Based Learning,
Mathematical Proficiency,
Meta-Analysis,
Bibliometric Analysis,
Moderator Variables,
Effect Size.

1. INTRODUCTION

The COVID-19 pandemic has caused one of history's most significant educational disruptions, primarily attributed to widespread school closures that impacted approximately 95% of the global student population (UN Policy Briefs, 2020). As a consequence, education globally has experienced a significant decline, especially in the subject of mathematics. This decline can be seen from the results of the PISA 2022 assessment.

On average, OECD countries had an unprecedented drop in performance, based on the PISA 2022 results. Compared to 2018, the mean performance dropped nearly 15 score points in mathematics. The decrease in mathematics performance is three times larger than any previous consecutive change (OECD, 2022). Figure 1 illustrates the global mathematics scores in PISA 2022.

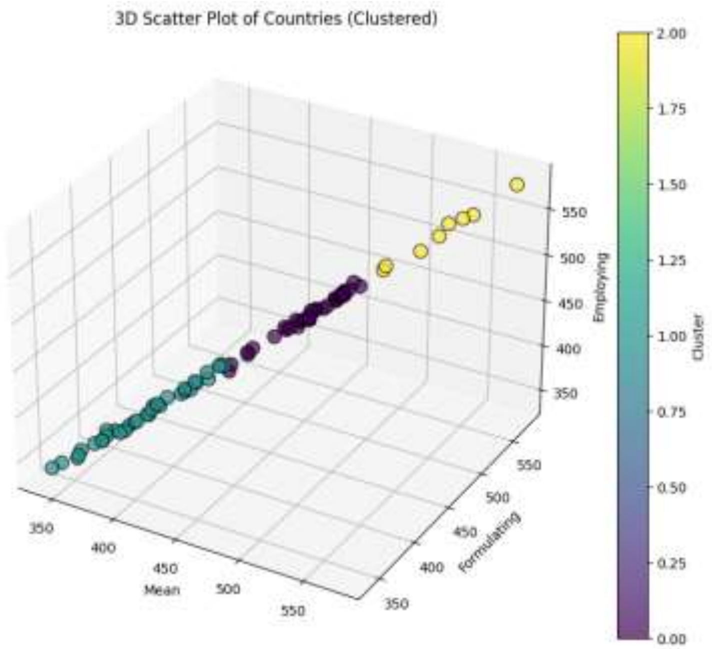


Figure 1. Mathematics Scores in PISA 2022

The findings from PISA 2022 indicate that, on average, 61% of OECD countries are below the average mathematics performance. However, 31% of students demonstrated performance below Level 2 in mathematics. Moreover, 19% of students achieved proficiency at Level 1a, 10% at Level 1b, 2% at Level 1c, and 0.3% below proficiency at Level 1c. Proficiency Level 2 is recognized as the foundational level of competence that students are required to engage actively in society. However, students below the baseline Level 2 have low mathematical proficiency.

Mathematical proficiency refers to an individual's capacity in mathematics that can be utilized and applied across diverse fields (Rohimah et al., 2022). Additionally, conceptual understanding, strategic competence, procedural fluency, productive disposition and adaptive reasoning are the five fundamental components of mathematical proficiency (Kilpatrick et al., 2002). An important characteristic of mathematical proficiency is these five strands interconnected and interdependent nature. The interconnectedness of the five strands can provide valuable insights into the potential learning challenges that students may encounter in their long-term engagement with mathematics (Corrêa & Haslam, 2020).

DOI: http://dx.doi.org/ 10.17509/jds.v1i2.65591
p- ISSN 2987-856X e- ISSN 2987-7512

The low level of mathematics proficiency may arise from various factors, including the utilization of inappropriate learning models, leading to students' lack of active engagement in learning (Rahmah et al., 2023). Furthermore, the teaching process has not encouraged students to think scientifically, and the learning model is still conventional (Zulyusri et al., 2022). However, an instructional model that can improve the way students learn mathematics is required (Rahman et al., 2023). One way to enhance mathematical proficiency is by employing problem-based learning (Tanjung et al., 2020).

Problem-based learning is a method of instruction that emphasizes for solving particular problems to increase student engagement in the learning process (Şenyiğit & Yüzüncü, 2021). PBL is an instructional approach that facilitates the growth and advancement of students for their research, questioning, initiative, and decision-making skills (Bayram & Deveci, 2022). Developing problem-solving abilities is an essential skill that students must possess in order to effectively learn mathematics (Muhaimin et al., 2023). All educational levels require that students learn how to solve problems (Purwasih et al., 2023). However, problem-solving requires individuals to engage in creative and critical thinking to generate alternative ideas and identify specific steps to overcome challenges (Hasibuan et al., 2018).

According to (Cahyaningsih et al., 2023), PBL will improve students' mathematical proficiency. These outcomes are in line with (Darwani et al., 2020). However, demonstrates the implementation of the Problem-Based Learning framework to instruction improves students' ability to develop adaptive reasoning and strategic competence. Students are guided to comprehend problems, engage in connecting concepts or situations, and subsequently identify the appropriate strategy to address the problem. The Problem-Based Learning has the potential to be used in an attempt to enhance students' critical thinking abilities because it is effective at developing problem-solving skills through critical and creative thinking (Arifin et al., 2020). Additionally, problem-based learning demonstrated a more significant impact compared to conventional teaching in enhancing students' mathematics problem-solving ability, academic gain, and self-confidence in mathematics (Hendriana et al., 2018).

Several studies have indicated that the literature on PBL impacts students' mathematical proficiency. However, there has not been an in-depth investigation regarding how PBL affects students' mathematical proficiency in the literature. On the other hand, there is a need for a comprehensive determination by the government and relevant stakeholders concerning the efficacy of PBL, including the factors that shape its future implementation. Analyzing the impact of PBL on mathematical proficiency concerning study characteristics is not achievable through individual primary studies. Because meta-analysis uses effect sizes, it is regarded as an objective method for conducting literature reviews (Tamur et al., 2020).

Meta-analysis is a statistical methodology that employs quantitative procedures such as effect sizes, to determine the level of intensity of the connections between variables in the research included in the analysis (Cleophas & Zwinderman, 2017). This approach disregards subjective interpretations in different study reports focused on the similar problem or methodology (Borenstein et. al., 2009). Meta-analysis studies of the overall effects of PBL identify any relevant literature on mediators that should be taken into consideration in the future.

DOI: http://dx.doi.org/ 10.17509/jds.v1i2.65591
p- ISSN 2987-856X e- ISSN 2987-7512

With this particular framework, this study investigates following questions:

1. Are the effect sizes from PBL implementation greater than those from conventional mathematical approach?
2. Is the study's overall effect size affected by variations in the sample size, educational attainment, study year, strands of mathematical proficiency, and geographic area where PBL is implemented?

2. METHOD

Research Design

The objective of this research is to conduct a statistical assessment Regarding primary research investigating the effects of implementing Problem-Based Learning (PBL) on students' mathematical proficiency, using meta-analysis approach. The process of conducting the meta-analysis involves three steps. Firstly, the criteria for selecting the research studies that will be used in the meta-analysis will be discussed. The process for locating studies and categorizing the variables found in those studies will be described in the second section. Third, statistical techniques will be used to investigate how study variables and effect sizes relate to one another (Boronstein et. al., 2007). These stages were also implemented in the present investigation.

Inclusion Criteria

The subsequent criteria are employed to identify which publications are considered appropriate for inclusion in the analysis, in order with the research objectives: First, the analysis includes studies that have been selected from a range of experimental and quasi-experimental studies that compare students' mathematical proficiency using Problem-Based Learning (PBL) with those taught through conventional approaches. Second, the studies included in this focused synthesis were carried out during the previous decade (2013-2023) and published in English. Third, mean, sample size and standard deviation are the crucial statistical parameters for this transformation. In addition, the year of study, the strands of mathematical proficiency, the location, the educational level, and the class level are the primary pieces of information required to explore the research question.

Data Collection

Scopus and UPI repositories were databases used to track primary studies. The search terms "problem-based learning" was used to locate primary studies. However, data collection in meta-analysis needs to consider publication bias, which refers to the inclination of studies to be published to report larger and statistically more significant effects (Polanin et al., 2016). therefore, meta-analysis searches should strive to identify unpublished literature (Juandi et al., 2022). hence, the researcher utilized two data sources from the Scopus database and UPI repository to avoid publication bias.

This research followed the procedures provided in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). There are four stages guided by PRISMA, namely, identification, screening, eligibility, and inclusion (Suparman et al., 2021a). Figure 2 provides a PRISMA diagram.

DOI: http://dx.doi.org/ 10.17509/jds.v1i2.65591
p- ISSN 2987-856X e- ISSN 2987-7512

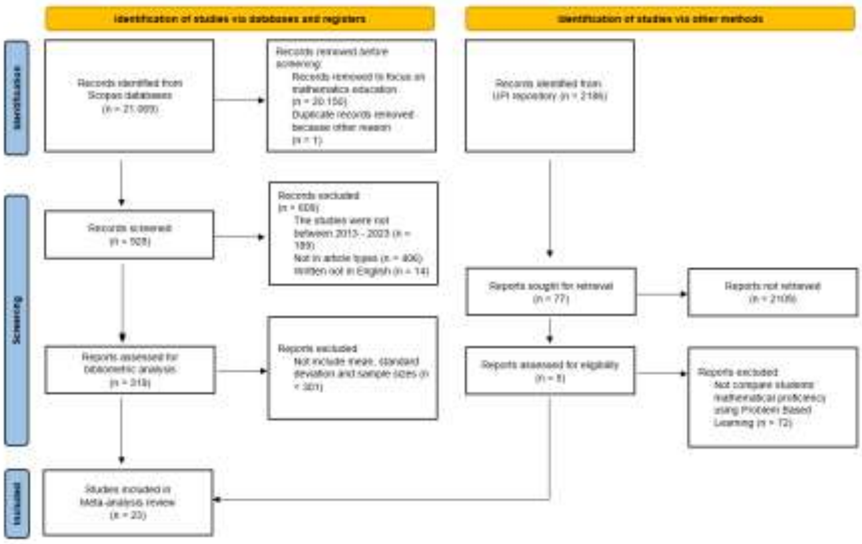


Figure 2. A flow diagram of PRISMA

Moderator Variables

Meta-analysis consistently identifies a moderating variable, which refers to the particular study's elements that relevant to the research findings (Hall & Rosenthal, 1991). In this study, a moderator represents a variable that influences PBL's impact. The coding of variables yields five discernible moderators, namely, the year of study, the strands of mathematical proficiency, the geographic area, the educational level, and the class level. Table 1 contains the information for the five moderators.

Table 1. Details regarding the moderator variables

Category	Group	N
Year of study	2013 – 2018	9
	2019 – 2023	14
Strands of mathematical proficiency	Conceptual understanding	6
	Procedural fluency	4
	Strategic competence	5
	Adaptive reasoning	4
	Productive disposition	4
Geographic area	Indonesia	18
	Turkey	1
	Bosnia and Herzegovina	1
	Taiwan	1
	United States	1
	Spanish	1
Educational level	Primary school	10
	Secondary school	6
	High school	7
Class Level	Small class (n < 30)	4
	Large class (n ≥ 30)	19

DOI: http://dx.doi.org/ 10.17509/jds.v1i2.65591
p- ISSN 2987-856X e- ISSN 2987-7512

Data Analysis

The data analysis of this research was carried out with a Comprehensive Meta-Analysis (CMA) application. An analysis was conducted utilizing the Hedges formulas to assess the effect size of integrating the PBL model on mathematical proficiency of students.

$$Hedges's\ g = \frac{\bar{X}_1 + \bar{X}_2}{S_{pooled}}$$

The g values obtained can be categorized into five categories (Thalheimer & cook, 2002), shown in Table 2.

Table 2. The categorization of effect size

Range of Effect Size (ES)	Interpretation
-0.15 ≤ ES < 0.15	Ignored
0.15 ≤ ES < 0.40	Low
0.40 ≤ ES < 0.75	Medium
0.75 ≤ ES < 1.10	High
1.10 ≤ ES < 1.45	Very high
ES ≥ 1.45	Very good

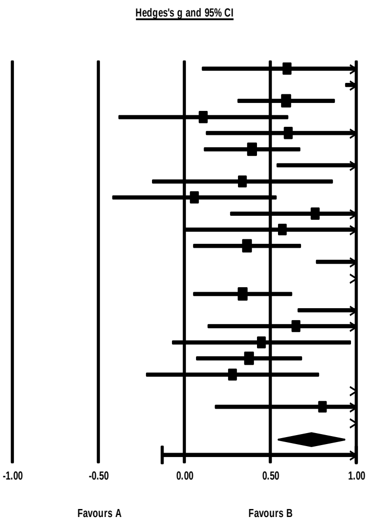
3. RESULTS AND DISCUSSION

Results of the Overall Analysis

This study first investigated to determine how PBL affects students' overall mathematical proficiency. Figure 3 explain the hedges's g, standard errors, confidence intervals, and Z-value and P-value among the studies addressed throughout the meta-analysis review.

Meta Analysis

Study name	Statistics for each study							Sample size	
	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	Eksperiment	Control
Ahmad, S., Mufidah, I., Aryanti, D., & Ghazali, M. H. (2023)	0.598	0.253	0.064	0.103	1.093	2.367	0.018	31	33
Ramadhani, R., & Narpila, S. D. (2018)	1.436	0.255	0.065	0.936	1.936	5.628	0.000	38	38
Sundayana, R., Herman, T., Dahlan, J. A., & Prahmana, R. C. (2017)	0.592	0.144	0.021	0.310	0.874	4.114	0.000	101	99
Ramadhani, R., Rofiqul, U. M. A. M., Abdurrahman, A., & Syazali, M. (2019)	0.110	0.252	0.063	-0.383	0.603	0.438	0.661	33	29
Rahmi, N., Arnawa, I., & Yerizon, Y. (2019)	0.605	0.244	0.060	0.126	1.083	2.477	0.013	37	32
Arifin, S., Setyosari, P., Sa'dijah, C., & Kuswandi, D. (2020)	0.394	0.143	0.020	0.114	0.673	2.761	0.006	97	102
Lestari, I., Kesumawati, N., & Ningsih, Y. L. (2020)	1.102	0.288	0.083	0.537	1.668	3.822	0.000	27	27
Li, H. C., & Tsai, T. L. (2022)	0.338	0.268	0.072	-0.187	0.863	1.262	0.207	28	27
Demitra, & Sarjoko. (2018)	0.059	0.243	0.059	-0.418	0.536	0.241	0.809	33	33
Hendriana, H., Johanto, T., & Sumarmo, U. (2018)	0.761	0.252	0.064	0.267	1.256	3.019	0.003	33	33
Gearing, N. V., & Hart, L. C. (2019)	0.571	0.294	0.087	-0.006	1.148	1.938	0.053	26	21
Napitupulu, E. E., Suryadi, D., & Kusumah, Y. S. (2016)	0.365	0.160	0.025	0.052	0.678	2.286	0.022	79	79
Ahdhianto, E., Marsigit, H., & Nurfauzi, Y. (2020)	1.247	0.245	0.060	0.766	1.728	5.082	0.000	39	39
Çetinkaya, L. (2019)	1.596	0.289	0.083	1.030	2.162	5.525	0.000	31	31
Amin, A., Sudana, I., Setyosari, P., & Djatmika, E. (2021)	0.339	0.146	0.021	0.052	0.626	2.318	0.020	94	94
Sopha, Nurus. (2016)	1.199	0.275	0.076	0.660	1.738	4.358	0.000	31	30
Malmia, W., Makatita, S. H., Lisaholit, S., Azwan, A., Magfirah, I., Tinggapi, H., & Umanailo, M. C. B. (2019)	0.649	0.262	0.068	0.137	1.162	2.482	0.013	30	30
Santaolalla, E., Urosa, B., Martín, O., Verde, A., & Díaz, T. (2020)	0.449	0.265	0.070	-0.070	0.968	1.694	0.090	33	25
Biki?, N., Mari?i?, S. M., & Pikula, M. (2016)	0.376	0.157	0.025	0.069	0.684	2.402	0.016	88	77
Setiyaningsih, Trisna (2015)	0.280	0.256	0.066	-0.222	0.782	1.095	0.274	30	30
Hermawan, Dasari, D. (2015)	1.955	0.311	0.097	1.345	2.565	6.284	0.000	30	30
Fitriana, F. N. (2022)	0.804	0.319	0.102	0.179	1.429	2.520	0.012	20	21
Cilviani, C. (2022)	1.860	0.306	0.094	1.260	2.460	6.073	0.000	30	30
Pooled	0.737	0.099	0.010	0.544	0.930	7.475	0.000		
Prediction Interval	0.737			-0.128	1.602				



Meta Analysis

Figure 3. Flow forest research

DOI: http://dx.doi.org/ 10.17509/jds.v1i2.65591
p- ISSN 2987-856X e- ISSN 2987-7512

Figure 3 illustrates that the overall effect size ranges between 0.05 and 1.95 with a 95% confidence interval. However, there are inconsistencies in ES PBL, representing the mediator's impact on the mathematical proficiency of students. Table 3 presents an analysis of the study's outcomes based on the estimate technique.

Table 3. Description of meta-analysis results based on estimation method

Models	N	Hedges's g	95% Confidence Interval		Q
			Lower	Upper	
Fixed-effects	23	0.63	0.54	0.72	94.79
Random-effects	23	0.77	0.54	0.93	

Table 3 demonstrates the various distribution of the effect sizes. Consequently, this study's meta-analysis utilizes the random effects model. The effect size, as determined by the random-effects model, is 0.77, indicating that, compared to traditional learning, PBL-based learning has a substantial impact on students' mathematical proficiency. The result is achievable because mathematical proficiency pertains to the capacity for comprehending, performing calculations, applying reasoning, and actively participating (Groves, 2012). This finding align with the research results of (Cahyaningsih et al., 2023), which studies indicate that Problem-Based Learning enhances students' mathematical proficiency.

Additionally, to assess the presence of publication bias, consideration can be given to a funnel diagram. The funnel plot that was obtained for the study is shown in Figure 4.

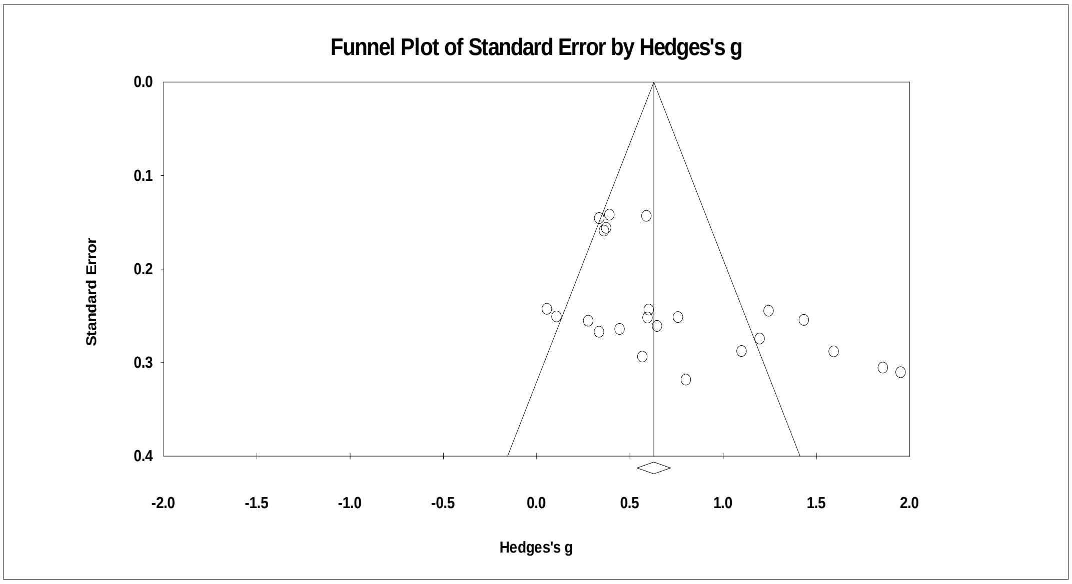


Figure 4. Research funnel plot

There is some non-perfect symmetry regarding the effect sizes' distribution. The decision was made for assessing potential publication bias using statistical data obtained through the calculation of FSN (Rosenthal's fail-safe N). Table 4 provides a summary of the findings from the N test calculations.

DOI: http://dx.doi.org/ 10.17509/jds.v1i2.65591
p- ISSN 2987-856X e- ISSN 2987-7512

Table 4. Results of statistical estimation for FSN

Bias Condition	Value
Z-value for observational investigations	14.63
P-value for observational investigations	0.00
Alpha	0.05
Tails	2
Z-value (for Alpha)	1.96
Number of empirical studies	23
FSN	1260

The results of the statistical evaluation conducted utilizing CMA software showed that the Rosenthal fail-safe N value was 1260, which is 1260 / (5 * 23 + 10), the calculated result is 10.08. It was observed that this value > 1. This result implies the research findings that were included from this study are not affected by the bias of publication. Consequently, there was no necessity to exclude or add any studies into the evaluation because of the bias of publication.

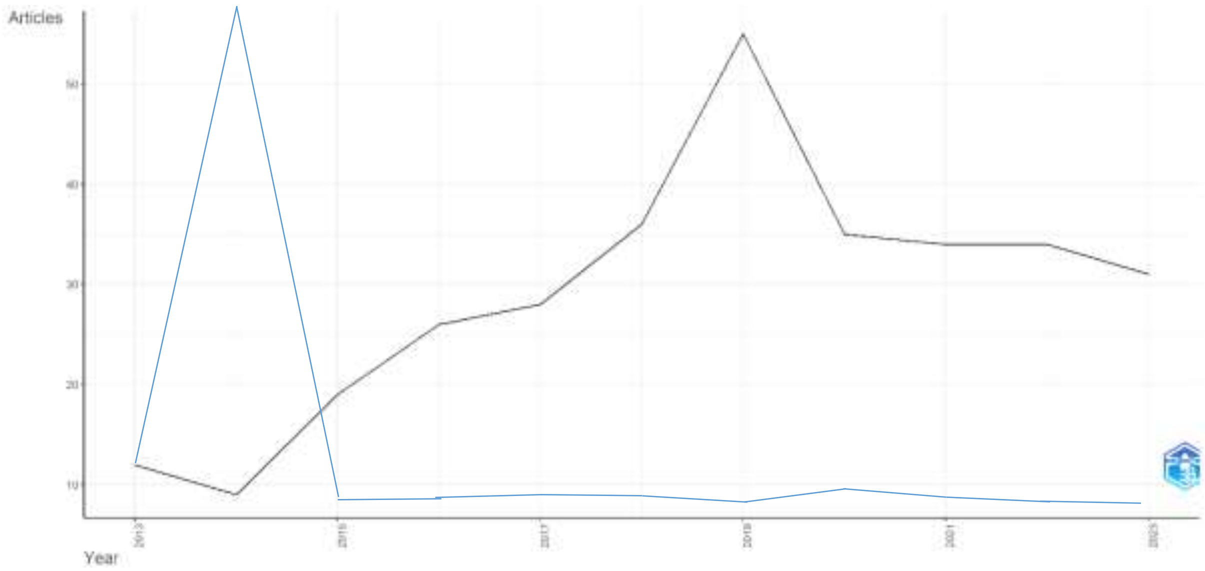
Results of the Moderator Variables based on Year of Study

Table 5. A description of the moderator variable results based on the study year

Year	N	Effect Size	Test of Null (Two Tailed)		Heterogeneity		
			Z – value	P – value	Q_b	df (Q)	P - value
2013 – 2018	9	0.74	4.41	0.00	0.003	1	0.96
2019 – 2023	14	0.73	5.85	0.00			

The characteristics of the year of study were divided into two groups: 2013 – 2018 and 2019 - 2023. There is little correlation in the value of the effect sizes of 0.73 (medium effect) in research conducted in 2019–2023 and 0.74 (medium effect) in studies conducted in 2013–2018. There was a p-value greater than 0.05. These findings interpret that there are no significant effects of PBL implementation for enhancing students' mathematical proficiency according to the year of study.

DOI: http://dx.doi.org/ 10.17509/jds.v1i2.65591
p- ISSN 2987-856X e- ISSN 2987-7512



: Annual scientific production : Average citation per year

Figure 5. Distribution and average citation of articles related to Problem-Based learning

Figure 5 illustrates the distribution and average citation of articles related to Problem-Based Learning between 2013 and 2023 at a 10-year interval. It is noticeable that the publication output saw a positive trend with the publication output in 2019 showing the most significant rise. Looking at the starting year, the publication output accounted for under 15 articles, which was the second lowest quantity of publications in the last 10 years. Over the following a half decade, the distribution of publications related to PBL saw an exponential trend. From 2013 to 209, the publication rate increased significantly. In stark contrast, in the next year, the publication rate decreased notably by approximately 25 articles. Finally, by the year 2023, the publication rate stayed around 32 articles.

On the other hand, the average citation of articles related to Problem-Based learning saw a dramatic increase in 2014, which was accounted for more than 45 articles but had a drastically drop in the next year by nearly 55 articles. Over the following years, the average citation of article saw a stagnant trends just under 10 articles every year until now.

Results of the Moderator Variables based on the Strands of Mathematical Proficiency

Table 6. A description of the moderator variable results based on mathematical proficiency

Strands	N	Effect Size	Test of Null (Two Tailed)		Heterogeneity		
			Z - value	P – value	Q_b	df (Q)	P – value
Conceptual understanding	*6*	*1.10*	5.22	0.00	10.52	4	0.033
Procedural fluency	*4*	*0.94*	2.84	0.00			
Strategic competence	*5*	*0.59*	3.08	0.00			
Adaptive reasoning	*4*	*0.44*	5.83	0.00			
Productive disposition	*4*	*0.61*	1.93	0.05			

DOI: http://dx.doi.org/ 10.17509/jds.v1i2.65591
p- ISSN 2987-856X e- ISSN 2987-7512

The strands of mathematical proficiency were divided into five groups, namely conceptual understanding, strategic competence, procedural fluency, productive disposition, and adaptive reasoning. The effect sizes in adaptive reasoning, strategic competence, and productive disposition are 0.44, 0.59, and 0.62, respectively, which were categorized as medium effects. In contrast, PBL implementation on procedural fluency and conceptual understanding has positive effects in improving students' mathematical proficiency. However, the effect sizes in both procedural fluency and conceptual understanding are 0.94 (high effect) and 1.10 (very high effect), respectively. The p-value was below 0,05. These findings reveal that the adoption of PBL considerably enhanced students' mathematical proficiency.

The finding aligns with (Suparman et al., 2021c), their analysis of nine original research on Problem-Based Learning (PBL) implementation on Indonesian students' high-order thinking skills indicates that PBL implementation has a substantial effect size, greatly enhancing Indonesian students' high-order thinking skills. (Suparman et al., 2021b) also found in the other research that the A meta-analysis on fifty research papers estimated the impact of Problem-Based Learning on developing skills of mathematical problem-solving in Indonesia was estimated at 0.817, indicating a larger effect size.

In network visualization, the connections between terms are shown as connections or lines that link one term to another, as shown in Figure 6.

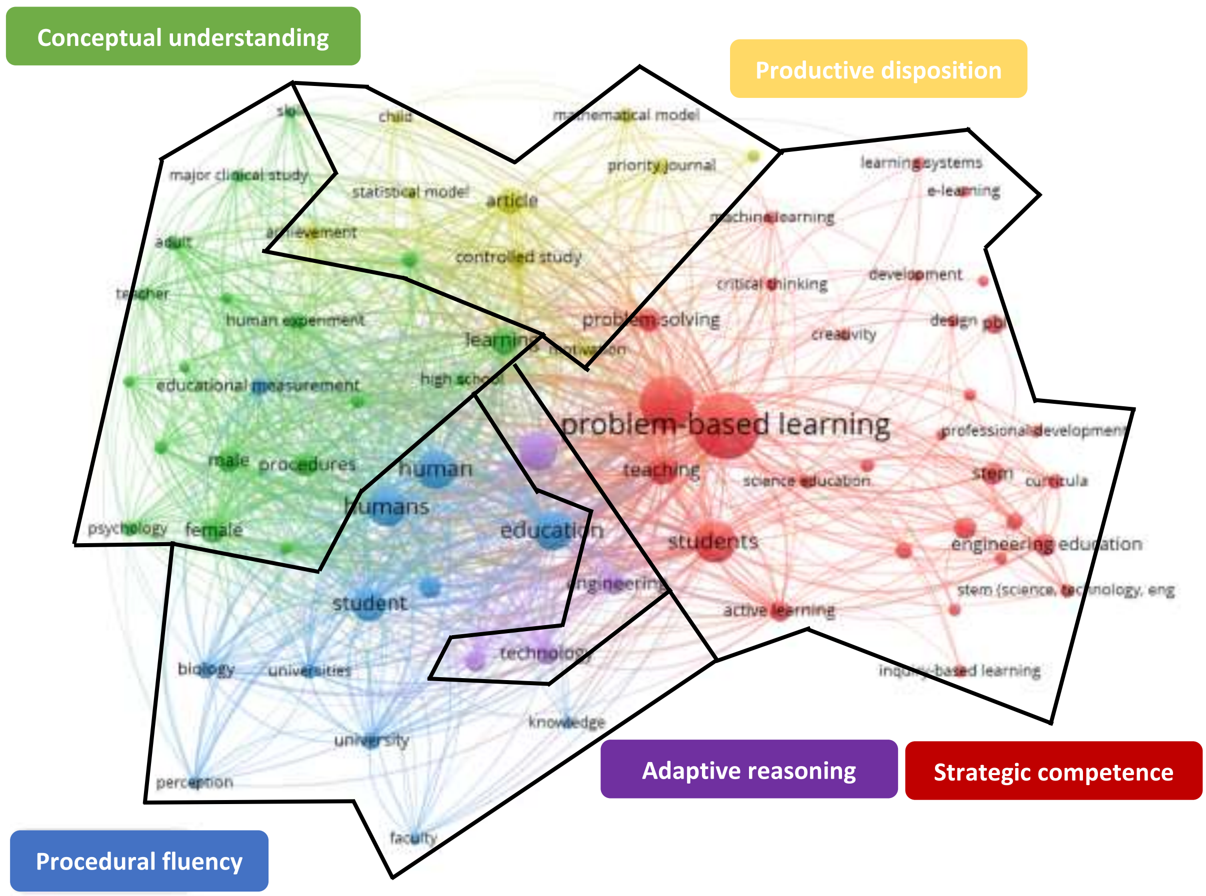


Figure 6. Co-occurrences of author keywords (network visualization)

DOI: http://dx.doi.org/ 10.17509/jds.v1i2.65591
p- ISSN 2987-856X e- ISSN 2987-7512

Results of the Moderator Variables based on Geographic Area

Table 7. Summary of the results of moderator variable based on geographic area

Geographic Area	N	Effect Size	Test of Null (Two Tailed)		Heterogeneity		
			Z – value	P – value	Q_b	df (Q)	P – value
Indonesia	*18*	*0.76*	6.68	0.00	16.77	5	0.005
Bosnia and Herzegovina	*1*	*0.38*	2.40	0.02			
Spain	*1*	*0.45*	1.69	0.09			
Taiwan	*1*	*0.39*	1.26	0.21			
Turkey	*1*	*1.60*	5.52	0.00			
United States	*1*	*0.57*	1.94	0.05			

The characteristics of the geographic area were divided into six groups: Indonesia, Bosnia and Herzegovina, Spain, Taiwan, Turkey, and the United States. The effect sizes of variables used as moderators in Bosnia and Herzegovina and Taiwan are only 0.38 and 0.39, respectively, which was categorized as low effect. The effect sizes found in studies from Taiwan and Bosnia and Herzegovina are similar to those in research from Spain (0.45) and the United States (0.57), both of which were classified as having a medium effect.

In contrast, PBL implementation in Indonesia and Turkey has positive effects in improving students' mathematical proficiency. However, the effect sizes in both Indonesia and Turkey are 0.76 (high effect) and 1.60 (very good effect), respectively. The p-value was below 0.05. The results presented indicate that the implementation of PBL has had a major beneficial effect on mathematical proficiency based on their geographic location.

Figure 7 illustrates the average scientific production based on the characteristics of the geographic area.

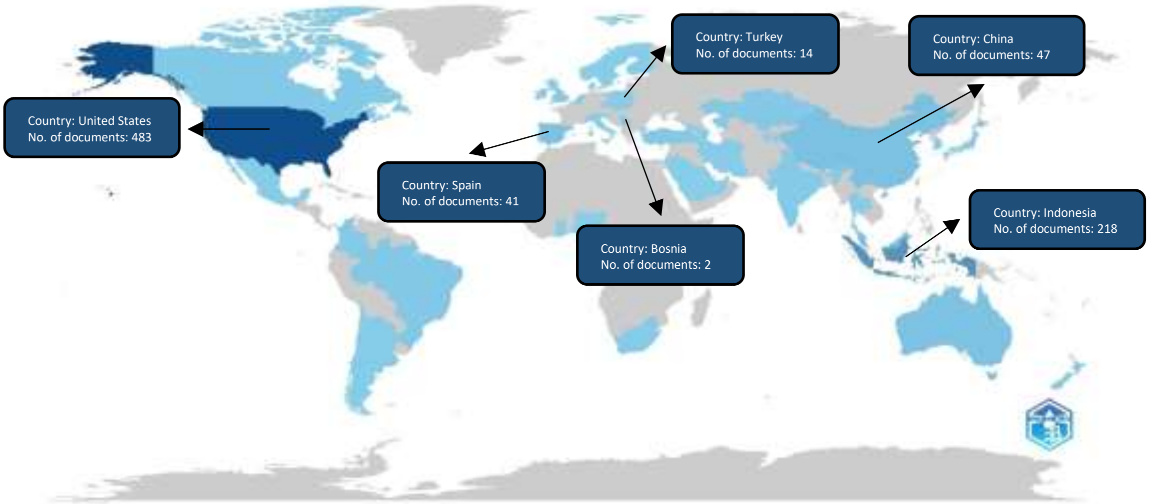


Figure 7. Country scientific production related to problem-based learning

DOI: http://dx.doi.org/ 10.17509/jds.v1i2.65591
p- ISSN 2987-856X e- ISSN 2987-7512

Results of the Moderator Variables based on the Level of Education

Table 8. Summary of the results of moderator variable according to level of education

Educational Level	N	Effect Size	Test of Null (Two Tailed)		Heterogeneity		
			Z – value	P - value	Q_b	df (Q)	P – value
Elementary school	*10*	*0.92*	4.95	0.00			
Secondary school	*6*	*0.71*	4.47	0.00	2.79	2	0.25
High school	*7*	*0.52*	3.39	0.00			

The educational level were divided into three groups: elementary, secondary, and high school. There is small difference between the 0.71 (medium impact) effect size in secondary school and the 0.52 (medium effect) effect size from high school studies. In contrast, PBL implementation in elementary school has positive effects in improving students' mathematical proficiency. However, the effect size observed in studies carried out in elementary school is 0.92, indicating a high level of effect. The p-value was greater than 0,05. These findings interpret that there are no significant effects of PBL implementation for enhancing students' mathematical proficiency according to the educational level.

In overlay visualization, the relationships between every educational level are represented as connections or lines that link one term to another, as shown in Figure 8.

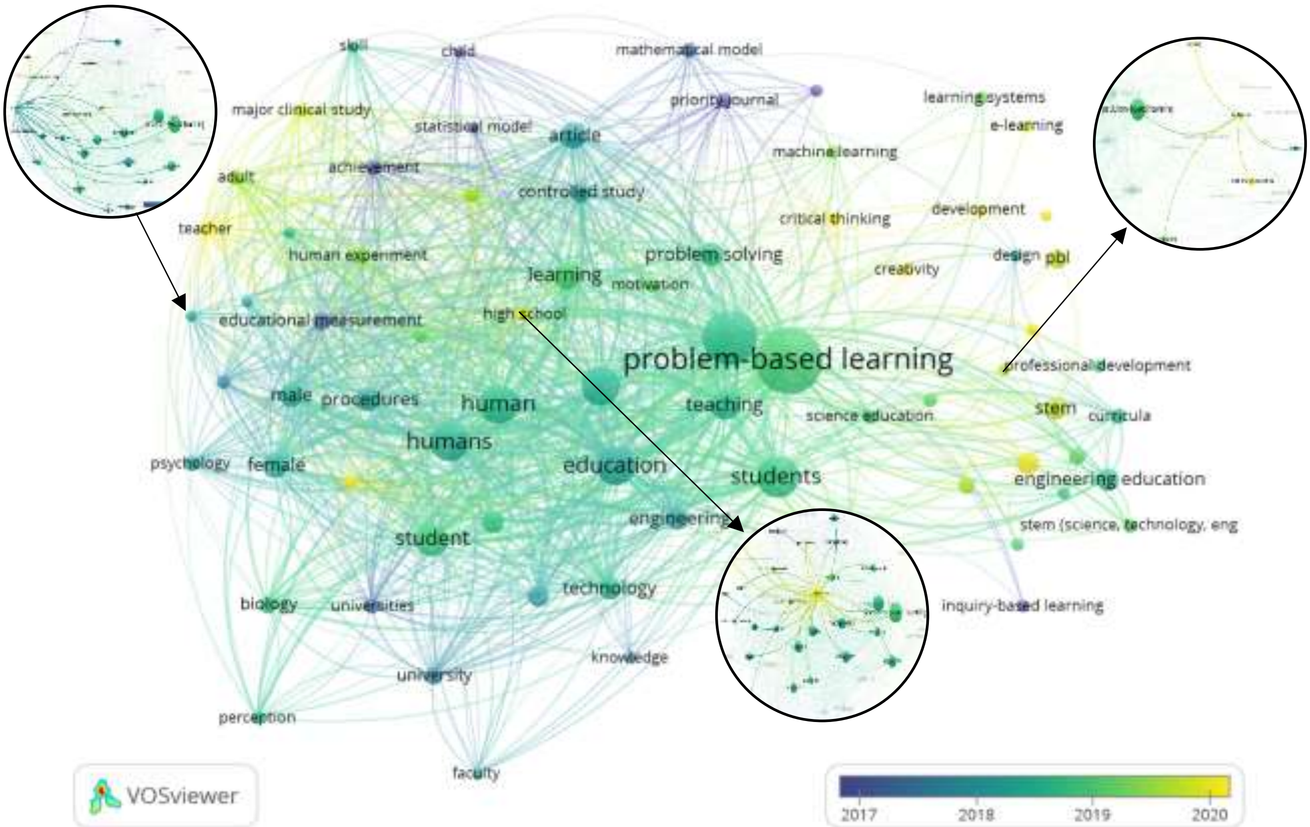


Figure 8. Co-occurrences of author keywords (overlay visualization)

DOI: http://dx.doi.org/ 10.17509/jds.v1i2.65591
p- ISSN 2987-856X e- ISSN 2987-7512

Results of the Moderator Variables based on Class Level

Table 9. Summary of the results of moderator variable based on class level

Class Level	N	Effect Size	Test of Null (Two Tailed)		Heterogeneity		
			Z – value	P – value	Q_b	df (Q)	P – value
Small class	*4*	*0.69*	4.08	0.00	0.08	1	0.78
Large class	*19*	*0.75*	6.67	0.00			

The characteristics of the class level were divided into two groups, namely: small class ($n < 30$) and large class ($n \geq 30$). Studies conducted in small classes showed a value of effect size of 0.69, Categorized as having a moderate impact. However, research conducted in large classes found the effect measured at 0.75 has been classified as a large effect. The p-value exceeded 0.05. These results reveal that there are no significant effects of PBL implementation for enhancing students' mathematical proficiency according to class level.

4. CONCLUSION

Over the past few decades, research investigations have been carried out to incorporate conclusions from the consequences associated with implementing Problem-Based Learning (PBL). When compared to conventional learning, some important findings indicate that the actualization of PBL significantly improves mathematical proficiency of students. PBL works effectively when it is applied to improve the strands related to understanding of concepts and knowledge of procedures of mathematical proficiency. However, it might not be recommended to enhance students' adaptive reasoning. However, the application of PBL is recommended in the large classes at the elementary schools. PBL is ideal for implementation in Turkey and Indonesia than it is in the US, Bosnia and Herzegovina, Spain, or Taiwan.

It is important to remember that although this analysis indicates a strong positive impact of using problem-based learning (PBL) on mathematical proficiency of students, this finding has only been drawn on research that consider effect sizes to be calculated. Several comparable research remain unanalyzed due to insufficient statistical information, highlighting a limitation within the context of the results. This study has certain limitations: first, the exclusion of certain study characteristics such as the duration of Project-Based Learning (PBL) treatments, the proficiency of PBL facilitators, the specific mathematics learning topics, and others. Second, a relatively limited number of primary studies, particularly those sourced from Web of Science (WoS), Publish or Perish (PoP), PubMed, and other sources. A manual investigation through library visits is essential to access unpublished sources, including undergraduate theses, theses and dissertations. Collaborative studies among nations regarding the impact of Project-Based Learning (PBL) will be crucial in the future to generate more comprehensive and inclusive results.

5. ACKNOWLEDGEMENTS

The funding for this study was provided by the Ministry of Research, Technology and Higher Education of Indonesia through the PMDSU scheme in the year 2020.

DOI: http://dx.doi.org/ 10.17509/jds.v1i2.65591
p- ISSN 2987-856X e- ISSN 2987-7512

6. REFERENCES

Arifin, S., Setyosari, P., Sa'dijah, C., & Kuswandi, D. (2020). The effect of problem-based learning by cognitive style on critical thinking skills and students' retention. *Journal of Technology and Science Education*, *10*(2), 271–281. https://doi.org/10.3926/JOTSE.790

Al Husaeni, D.F., Nandiyanto, A.B.D. (2022) Bibliometric computational mapping analysis of publications on mechanical engineering education using vosviewer. *Journal of Engineering Science and Technology*, *17*(2), 1135-1149.

BAYRAM, H., & DEVECİ, H. (2022). The Effect of Problem-Based Learning on Students' Entrepreneurship Level in Social Studies Course. *International Journal of Contemporary Educational Research*, *9*(2), 359–377. https://doi.org/10.33200/ijcer.1056504

Borenstein, M., Hedges, L., & Rothstein, H. (2007). Meta-analysis fixed effects vs. random effects.

Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2009). Introduction to meta-analysis. West Sussex, UK: John Wiley & Sons, Ltd

Cahyaningsih, U., Jatisunda, M. G., & Kurniawan, D. T. (2023). *Implementing Problem-Based Learning to Enhance Students ' Mathematical Proficiency in Primary School*. *4185*, 281–299.

Cleophas, J. T., & Zwinderman, H. A. (2017). *Modern meta-analysis: Review and update of methodologies*. Springer International Publishing Switzerland.

Corrêa, P. D., & Haslam, D. (2020). Mathematical proficiency as the basis for assessment: A literature review and its potentialities. *Mathematics Teaching-Research Journal*, *12*(4), 3–20.

Darwani, Zubainur, C. M., & Saminan. (2020). Adaptive reasoning and strategic competence through problem based learning model in middle school. *Journal of Physics: Conference Series*, *1460*(1), 0–5. https://doi.org/10.1088/1742-6596/1460/1/012019

Groves, S. (2012). SEAMEO Regional Centre for Education in Science and Mathematics. *Journal of Science and Mathematics Education in Southeast Asia*, *35*(2), 119–145. http://hdl.handle.net/10536/DRO/DU:30051321

Hall, J. A., & Rosenthal, R. (1991) Testing for moderating variables in meta-analysis: Issues and methods. Communication Monographs, 58, 437- 448.

Hasibuan, A. M., Saragih, S., & Amry, Z. (2018). Development of Learning Materials Based on Realistic Mathematics Education to Improve Problem Solving Ability and Student Learning Independence. *International Electronic Journal of Mathematics Education*, *14*(1), 243–252. https://doi.org/10.29333/iejme/4000

Hendriana, H., Johanto, T., & Sumarmo, U. (2018). The role of problem-based learning to improve students' mathematical problem-solving ability and self confidence. *Journal on Mathematics Education*, *9*(2), 291–299. https://doi.org/10.22342/jme.9.2.5394.291-300

Juandi, D., Kusumah, Y. S., & Tamur, M. (2022). A Meta-Analysis of the last two decades of realistic mathematics education approaches. *International Journal of Instruction*, *15*(1), 381–400. https://doi.org/10.29333/iji.2022.15122a

Kilpatrick, J., Swafford, J., & Findell, B. (2002). Helping Children Learn Mathematics. In *Helping Children Learn Mathematics*. https://doi.org/10.17226/10434

Muhaimin, L. H., Siswanto, R. D., Setiaputra, F. I., & Ridho, M. H. (2023). Students' Mathematical Problem-Solving Process on Minimum Competency Assessment Test in the Context of Local Wisdom. *Journal of Didactic Studies*, *1*(1), 23–35.

OECD. 2022. PISA for Schools: How to join. OECD Publishing.

Polanin, J. R., Tanner-Smith, E. E., & Hennessy, E. A. (2016). Estimating the Difference Between

DOI: http://dx.doi.org/ 10.17509/jds.v1i2.65591
p- ISSN 2987-856X e- ISSN 2987-7512

Published and Unpublished Effect Sizes: A Meta-Review. *Review of Educational Research*, *86*(1), 207–236. https://doi.org/10.3102/0034654315582067

Purwasih, R., Turmudi, T., Dahlan, J. A., & Irawan, E. (2023). Semiotic Perspective in Mathematics Problem-solving. *Journal of Didactic Studies*, *1*(1), 36–46. https://ejournal.upi.edu/index.php/jds/article/view/59022%0Ahttps://ejournal.upi.edu/index.php/jds/article/viewFile/59022/23022

Rahmah, I. F., Irianto, A., & Rachmadtullah, R. (2023). Problem Based Learning Models to Numeracy Literacy Skills : A Study in Elementary School. *Journal of Education and Teacher Training Innovation*, *1*(1), 1–10. https://doi.org/10.61227/jetti.v1i1.4

Rahman, A., Ilwandri, I., Santosa, T. A., Gunawan, R. G., Suharyat, Y., Putra, R., & Sofianora, A. (2023). Effectiveness of Problem-Based Learning Model in Science Learning: A Meta-Analysis Study. *JUARA : Jurnal Olahraga*, *8*(2), 713–726. https://doi.org/10.33222/juara.v8i2.3128

Rohimah, Darhim, & Juandi, D. (2022). Hypothetical Learning Trajectory in STEM Approach with Project-Based Learning Model to Improve Students' Mathematical Proficiency. *Italienisch* , *12*(1), 121–127.

Şenyiğit, Ç., & Yüzüncü, V. (2021). the Effect of Problem-Based Learning on Pre-Service Primary School Teachers' Conceptual Understanding and Misconceptions. *International Online Journal of Primary Education (IOJPE)*, *10*(1), 50–72. www.iojpe.org

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). Review of problem-based learning trends in 2010-2020: A meta-analysis study of the effect of problem-based learning in enhancing mathematical problem-solving skills of Indonesian students. *Journal of Physics: Conference Series*, *1722*(1). https://doi.org/10.1088/1742-6596/1722/1/012103

Suparman, S., Juandi, D., & Tamur, M. (2021c). Does Problem-Based Learning Enhance Students' Higher Order Thinking Skills in Mathematics Learning? A Systematic Review and Meta-Analysis. *ACM International Conference Proceeding Series*, *April*, 44–51. https://doi.org/10.1145/3451400.3451408

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

Tanjung, D. F., Syahputra, E., & Irvan, I. (2020). Problem Based Learning, Discovery Learning, and Open Ended Models: An experiment On Mathematical Problem Solving Ability. *JTAM | Jurnal Teori Dan Aplikasi Matematika*, *4*(1), 9. https://doi.org/10.31764/jtam.v4i1.1736

Thalheimer, W., & Cook, S. (2002). How to calculate effect size from published research: a simplified spreadsheet

The Impact of COVID-19 on Children. UN Policy Briefs (United Nations, 2020).

Zulyusri, Elfira, I., Violita, & Santosa, T. A. (2022). Meta-Analysis Study : Correlation Study of the Influence of Motivation on Student Learning Outcomes. *International Journal of Education and Literature (IJEL)*, *1*(3), 34–45.

DOI: http://dx.doi.org/ 10.17509/jds.v1i2.65591
p- ISSN 2987-856X e- ISSN 2987-7512