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Meta-Analysis: The Effect of The Problem Based Learning Model in Improving Students' Mathematical Literacy

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a b s t r a c t

Mathematical literacy is important to help students solve problems in real life, but the achievement of Indonesian students is still low. The Problem Based Learning model is considered effective in improving mathematical literacy because it focuses on solving real problems and student activities. This study aims to analyze the effect of the Problem Based Learning model on improving students' mathematical literacy through a Meta-Analysis approach to five nationally accredited articles published in the 2020-2025 period. Based on the calculation results, the average pretest score was 45.85 and the posttest score was 75.58, so there was an increase after the Problem Based Learning model implementation. The average effect size in the high category, as determined by the effect size computation, was 2. 042. According to the t-test findings, before and after the Problem Based Learning approach was implemented, there was a noticeable change in the average scores of students' mathematical literacy on the pretest and posttest, specifically the calculated t value > t table = 7.530 > 1.656 This study's findings suggest that the issue is Mathematical literacy is significantly enhanced by based learning. However, several studies have shown that success is influenced by grade level and supporting media such as Geogebra and e-LKPD. Therefore, Problem-Based Learning can be a highly effective learning alternative for improving mathematical literacy. Its implementation needs to be continuously developed, taking into account learning design, technology integration, and teacher readiness to ensure optimal and sustainable results.

Keywords:
Problem Based Learning; Mathematical Literacy; Meta Analysis

INTRODUCTION

The process of learning mathematics requires thinking skills that are applied in various dynamic field conditions as well as mathematical reasoning skills in describing, explaining, using techniques, data and tools, these skills are called mathematical literacy (Hidayat et al., 2019). According to Kusumawardani et al (2018) the importance of mathematical literacy for students is to emphasize the ability to analyze, provide arguments and solve mathematical problems that students encounter during the learning process in class and in real life. In PISA, indicators of mathematical literacy include the ability to formulate (*formulate*), use mathematical procedures (employ) and interpret results (interpret) (OECD, 2019).

Although mathematical literacy is considered an important competency, many studies show that students' mathematical literacy skills are still low and not optimal (Praneswari & Amidi, 2023). Indonesian students' mathematical literacy achievement in the 2022 PISA (Planning for International Student Assessment) remains relatively low, at around 366 points, well below the OECD average. However, Indonesia's position has shown slight improvement compared to previous PISA results (OECD, 2023). Sulfayanti (2023) Found that one of the factors causing low student mathematical literacy is the use of conventional teaching methods that provide minimal stimulation of high-level cognitive activities.

Applying appropriate approaches, methods, and models in learning can help students learn more easily and ultimately develop mathematical literacy skills (Kusumawati et al., 2024). Praneswari & Amidi (2023) stated that the use of the Problem Based Learning model consistently correlates with increased student mathematical literacy compared to conventional learning methods.

The Problem-Based Learning paradigm is a student-centered approach to learning that uses real-world issues as the foundation for the learning process (Firdaus et al., 2021). he learning process in Problem-Based Learning involves several steps: 1) Introduce the problem to students, 2) Organize students for the learning process, 3) Guide investigations both individually and in groups, 4) Design and deliver the work tasks, and 5) Analyze and assess the problem-solving methods (Delsi Novelni & Elfia Sukma, 2021). Junianto & Wijaya (2019) emphasized that Problem-Based Learning has significant potential to improve students' mathematical literacy skills from elementary to tertiary levels..

Findings from research conducted by Ahmad Gufron et al. (2025) indicate that the Problem-Based Learning method significantly improves mathematical literacy skills, with an effect size reaching 1.165, which is included in the very high category. On the other hand, a study by Paloloang et al. (2020) revealed that the use of problem-based learning was quite successful in improving students' mathematical literacy skills with a combined effect size of 0.830, which is considered high. Research conducted by Fardian & Dasari (2023) shows that the application of Problem-Based Learning results in an increase in mathematical literacy with a medium effect size of 0.77, which indicates that this model is effective although not very strong.

Based on this background, the researcher believes that further research is needed on the effect of the Problem-Based Learning model on improving students' mathematical literacy.

This study aims to provide insight and a basis for further research on the Problem-Based Learning model's impact on mathematical literacy skills.

METHODS

The goal of this research was to examine the results of earlier research on how the Problem-Based Learning approach affects the development of mathematical literacy abilities.The method used in this study was meta-analysis. Meta-analysis is a research that involves reviewing, collecting data, and analyzing various previous research results using statistical methods (Saputri & Wardani, 2021). The data were gathered by locating nationally-accredited articles that explored the use of the Problem-Based Learning model to enhance mathematical literacy. The keywords used by the researchers in the article search included "Problem-Based Learning," "PBL," and "mathematical literacy." The literature search process through the Publish or Perish application uses academic databases such as SINTA, Google Scholar, Garuda. By using inclusion criteria, researchers can filter and select the most relevant and useful studies to be included in the review, ensuring that the analysis carried out is based on strong and consistent evidence. Inclusion criteria were set for articles published in the 2020-2025 period, articles containing variables that are appropriate to the research, namely Problem Based Learning and mathematical literacy, nationally indexed journal, and the type of research is quantitative in which it contains statistical data containing sample size, average, and standard deviation.

The six steps of meta-analysis research data analysis are as follows: (1) identifying the problem or topic to be examined. The subject covered in this investigation (1) pertains to the effects of the Problem Based Learning approach on enhancing mathematical literacy; (2) seeks out and compiles publications that address the topic or. research reports; (3) recording as much data as possible from research reports. The data acquired covers things like the average mathematical literacy of pupils, the subject of study, and more. (4) Using the t-test to determine significance; (5) determining the effect size on the indicators of mathematical literacy employed; and (6) calculating the standard deviation from five papers. (6) examining previously published research papers by taking into account the methods and data analysis employed in each study report based on the data that has been acquired in order to come to conclusions (Rossytasari & Setyaningtyas, 2021).

*Effect Size is a value used to measure an effect*h (Cohen, 1988). The impact of employing the Problem-Based Learning model was evaluated in this study by calculating the effect size. The formula for calculating The effect size is listed below.

$$ES = \frac{\bar{x}_E - \bar{x}_c}{SD_G}$$

Description.

ES : *Effect Size*

$\bar{x}_E$: Mean posttest score

$\bar{x}_c$: Mean pretest score

SD_G: Pooled standard deviation

The combined standard deviation formula is as follows.

$$SD_G = \sqrt{\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2}}$$

Description.
SD_G : Pooled standard deviation
n_1 : Many pretest students
n_2 : Many students posttest
S_1^2 : Pretest variance
S_2^2 : Posttest variance

According to Cohen (1988), he results of the effect size can be interpreted into categories in the following Table 1.

Table 1
Category Effect Size

Effect Size (ES)	Category
$0 \leq ES \leq 0,2$	Low
$0,2 \leq ES \leq 0,8$	Medium
$ES > 0,8$	High

The goal of this study is to determine how the Problem-Based Learning model affects mathematical literacy. Therefore, hypothesis testing must be conducted using a t-test. The following is the formula used for the t-test.

$$t_{hitung} = \frac{\bar{x}_2 - \bar{x}_1}{\sqrt{\frac{(n_1 - n_2)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

Description.
$\bar{x}_1$: Average pretest score
$\bar{x}_2$: Average posttest score
n_1 : Number of pretest students
n_2 : Number of posttest students
S_1^2 : Pretest variance
S_2^2 : Posttest variance

The hypothesis in this study is as follows.

H_0: $\mu_1 = \mu_1$, There is no significant effect between the average pretest and posttest scores on the improvement of students' mathematical literacy before and after implementing the Problem Based Learning model.

H_1: $\mu_1 \neq \mu_1$, There is a significant effect of the average pretest and posttest scores on the improvement of students' mathematical literacy before and after applying the Problem Based Learning model.

RESULT AND DISCUSSION

Result

According to the criteria obtained, the number of articles that meet the inclusion criteria is 5, consisting of 2 articles indexed in SINTA 2, 2 articles indexed in SINTA 3, and 1 article indexed in SINTA 4. The selected sample data are presented in the following Table 2.

Table 2
Results of Articles that Meet the Criteria

No	Code	Article Title and Author	Level	Research result
1	J-1	Effect of Problem-Based Learning Assisted by E-LKPD Wizer.me on Students' Mathematical Literacy Skills (Setyawardani & Edy, 2024)	Junior High School	Research shows that after using the Problem Based Learning (PBL) model supported by E-LKPD Wizer.me, students' mathematical literacy skills experienced a significant increase. The students' average pretest score of 56.15 increased to 75.72 in the posttest. In addition, the standard deviation (SD) decreased from 19.58 to 15.19, indicating a more homogeneous variation in learning outcomes after the treatment. These findings prove that the PBL model assisted by e-LKPD Wizer.me is effective in improving junior high school students' mathematical literacy skills.
2	J-2	The Effect of GeoGebra-Assisted Problem-Based Learning on Students' Mathematical Literacy Skills and Learning Motivation (Purbaningrum & Mahmudi, 2024)	Vocational School	The results of the study showed a significant increase in mathematical literacy skills, where the average literacy score increased from 36.64 with SD 20.10 in the pretest to 68.27 with SD 17.40 in the posttest. The t-test showed a significance value of 0.000 < 0.05, which means the increase was statistically significant. Thus, the implementation of the GeoGebra-assisted PBL model has proven effective in improving mathematical literacy skills as well as learning motivation of vocational high school students.
3	J-3	Students' Mathematical Literacy Skills in Problem Based Learning (PBL) Model Learning (Tabun et al., 2020)	Junior High School	The results showed a significant improvement in students' mathematical literacy skills. The average pretest score of 43.48 increased to 86.87 in the posttest, with a standard deviation (SD) of 8.75. The gain score was 0.8, which

				is considered high. Therefore, the findings suggest that the implementation of the Problem-Based Learning model has a meaningful and positive impact on junior high school students' mathematical literacy skills.
4	J-4	The Effect of Problem Based Learning Model on Improving Mathematical Literacy Skills in Data Presentation Material (Musaad et al., 2023)	Junior High School	The average value of students' mathematical literacy rose from 49. 40 to 75. 04, according to the According to the data, the range was between 40 and 75. 04, with the standard deviation (SD) falling from 14. 58 to 10. 62. The results of the t-test yielded a significance value of 0. 000, which is less than 0. 05, demonstrating a notable rise. The N-Gain value achieved was 0.51, placing it in the moderate category. Thus, the application of the PBL model has proven effective in improving students' mathematical literacy skills, especially in data presentation materials.
5	J-5	Implementation of Problem Based Learning in an Effort to Improve Students' Mathematical Literacy (Sitompul et al., 2023)	senior high school	The study's findings demonstrated a notable improvement in students' mathematical literacy abilities, where the average pretest score of 43.57 (with SD 16.71) increased to 72.00 (with SD 9.87) in the posttest. The t-test results produced a significance value of 0.000 < 0.05, which means the increase was statistically significant. These results suggest that the Issue The Based Learning Problem is quite successful in enhancing high school students' mathematical literacy abilities.

The aforementioned publications provided the data for a meta-analysis. After that, Table 3 below displays the data, which looks at how well the problem-based learning approach enhances mathematical literacy.

Table 3
Pretest and Posttest Data Analysis

Code	N	Pretest Average	SD	N	Posttest Average	SD
J-1	27	56.15	19.58	27	75.72	15.19
J-2	33	36.64	20.10	33	68.27	17.40
J-3	30	43.48	16.22	30	86.87	8.75
J-4	25	49.40	14.58	25	75.04	10.62
J-5	30	43.57	16.71	30	72.00	9.87

examining the impact of the issue using the data collected to determine the effect size value, the learning model is based on the mathematical proficiency of the students. The degree to which a variable impacts other variables in the study, or the effect size value, is used to ascertain this. The effectiveness of a variable's impact on other variables is calculated using effect size (Cohen, 1988). The following table shows the effect size results from the collected research data.

Table 4
Effect Size Analysis Results

Code	*Effect Size* (ES)	Category
J-1	1,116817	High
J-2	1,682578	High
J-3	3,329571	High
J-4	2,010252	High
J-5	2,071706	High
Average	2,042185	High

Based on Table 4 above, five studies have high effect sizes. The average effect size of the five previous studies was 2.042185, categorized as high. Thus, The Problem-Based Learning approach has a strong or significant impact on students' mathematical literacy. Educational level is one aspect of the data that can be analyzed. In this study, the educational levels found were junior high school, vocational high school, and senior high school. The effect size values based on educational level are presented in Table 5.

Table 5
Results of Effect Size Analysis Based on Level

Code	Level	Effect Size (ES)	Average	Category	Amount
J-1	SMP	1,116817			
J-3		3,329571	2,152213	High	3
J-4		2,010252			
J-2	SMK &	1,682578	1,877142	High	2
J-5	SMA	2,071706			

The effect size values for the junior high school (SMP) and vocational/senior high school (SMK/SMA) levels were in the high range, as shown in Table 5. The average effect size for junior high school students was 2. 152213, which is considered to be in the high range, whereas the average effect size for vocational and senior high school students was 1. 284201, which is considered to be in the medium range. The student ratio, which was rated as high, was 1. 877142. As a result, the Problem-Based Learning approach has a big impact on students' mathematical literacy at the middle school and vocational/high school levels.

The variance between pre-test and the post-test scores for mathematical literacy, collected before and after the implementation of the Problem-Based Learning model, were then analysed using a t-test. Table 6 summarises the results of that t-tes.

Table 6
t-Test Results

Artikel Code	Average	Dk	t_{count}	t_{table}	Criteria	Conclusion
Pretest	45,85	145-2=143	7,530	1.656	$t_{count} > t_{table}$ So H_0 is rejected	There is a significant influence
Posttest	75,58					

The t-test results listed above show that $t_{count} > t_{table}$ that is 7,530 > 1.656, hence H_0 is rejected. Consequently, it can be concluded that there is a significant difference between the mean pre-test and post-test scores for students' mathematical literacy before and after implementing the Problem-Based Learning model.

The study's findings, mentioned above, revealed variations in pupils' mathematical literacy pre- and post-test scores when using the Problem Based Learning method. The average pretest score of 45. 85 and posttest score of 75. 58 demonstrates the improvement in pupils' mathematical literacy, resulting in a rise in their average score. From the effect size values we got, we may deduce a highly notable rise with an ES value of 2. 042185, suggesting that the impact of the Problem is significant. Students' mathematical literacy is in the high category in the Based Learning model.

Discussion

Based on Table 4, the effect size values for each article reviewed are obtained. Effect size is a measure of the level of correlation or difference between one variable and another. Study Setyawardani & Edy (2024) The results showed that the Problem Based Learning model assisted by E-LKPD Wizer.me had a significant effect on students' mathematical literacy with an effect size of 1.11, which is in the high category. The average literacy score increased from 56.15 to 75.72 after the model was implemented in eighth-grade students of SMP Islam Manbaul Ulum Gresik. According to research conducted by Huda (2014) mathematical literacy increased by 81%. The findings of this study are consistent with previous research on Problem-Based Learning at MAN 1 Gresik, and supported by research Paloloang et al (2020) The results of his research showed an average effect size of 0.83, indicating a strong influence of Problem Based Learning on mathematical literacy. Besides that, Rismayanti & Wahyuni (2022) also demonstrated a significant difference in mathematical literacy skills between students who studied with Problem-Based Learning and those who studied conventionally. Thus, implementing the Problem-Based Learning model with the aid of digital media such as E-LKPD Wizer.me has proven effective in improving students' mathematical literacy.

Study Purbaningrum & Mahmudi (2024) obtained an effect size of 1.68, categorized as high, indicating that the GeoGebra-assisted Problem Based Learning model significantly impacted students' mathematical literacy. The average literacy score increased from 36.64 to 68.27 after the implementation of the Problem Based Learning model for 11th-grade vocational high school students. This result is in line with research Kusumawati et al (2024) who found that the application of the GeoGebra-assisted Problem Based Learning model was effective in improving students' mathematical literacy skills. Furthermore,

Fitriani et al (2023) also proved that the implementation of Problem Based Learning assisted by GeoGebra can significantly improve mathematical literacy skills. In addition, Anzani & Juandi (2022) In their research, they obtained an effect size of 1.32, confirming that the combination of Problem-Based Learning and GeoGebra significantly impacted mathematical literacy. Thus, the implementation of the GeoGebra-assisted ProblemBased Learning model has proven effective in improving students' mathematical literacy.

Then the research was conducted Tabun et al (2020) obtained an effect size of 3.32, which is in the high category, indicating that the Problem Based Learning model has a significant effect on students' mathematical literacy. The average mathematical literacy score increased from 43.48 to 86.87 after implementing the Problem Based Learning model on students at South Mollo 1 Christian Middle School. This result is in line with Fathurrohman et al (2023) which states that the Problem Based Learning model with a scaffolding approach is able to improve students' mathematical literacy. As well as Ahmad Gufron et al (2025) According to meta-analysis, the Problem Based Learning approach has a big impact on mathematical literacy at all grades. The Problem Based Learning approach has thus been shown to be successful in enhancing students' mathematical literacy.

Next, research Musaad et al (2023) The results showed that the implementation of the Problem Based Learning model had a significant effect on students' mathematical literacy with an effect size of 2.01, which is in the high category. The average mathematical literacy score of seventh-grade students at SMPIT Al-Izzah, Sorong City increased from 49.40 to 75.04 after the implementation of Problem Based Learning. These results are in line with research conducted by Erria et al (2023) reported that the Problem Based Learning approach has a large impact on students' mathematical literacy abilities, with an effect size of 0. 88 in the high category. In addition, research by Wahyudi (2024) also showed an effect size of 1.465 for the mathematical literacy variable. It can be concluded that consistently applying the Problem-Based Learning model exerts a strong effect on enhancing students' mathematical literacy.

Lastly, in the research conducted by Sitompul et al (2023) The effect size value was 2. 07, which is deemed high, indicating that the Problem Based Learning approach has a big impact on students' mathematical literacy. This is indicated by the difference in the average pretest and posttest on students' mathematical literacy abilities. The average initial mathematical literacy score was 43.57, but after implementing the Problem Based Learning model, the average mathematical literacy score of SMA Yadika 5 Jakarta students increased to 72. These results are in line with research conducted by Pamungkas & Franita (2019) which shows that the application of the Problem Based Learning model can significantly improve the mathematical literacy skills of junior high school students compared to conventional learning. In addition, Ekaputri & Simanjorang, (2022) also mentioned that the introduction of the Problem Based Learning approach in mathematics education resulted in an improvement in students' mathematical literacy. The implementation of the Problem-Based Learning model was shown to have a steady positive effect on students' mathematical literacy.

The results of the t-test and literature review show that the Problem Based Learning model has a significant positive influence on students' mathematical literacy at both junior

high and vocational high school/Islamic high school levels, taking into account the use of tools such as Geogebra, e-LKPD, Wizer.me or not.

CONCLUSION

Based on the analysis of five studies conducted, it was found that the use of the Problem Based Learning learning model has a significant and strong impact in improving students' mathematical literacy skills. The average effect size reaching 2.042 indicates that the Problem Based Learning model is in the high impact category, which means that the application of this model has a significant impact on students' mathematical literacy. Furthermore, the results indicated a statistically significant increase in the average scores from the pre-test to the post-test, where the initial value of 45.85 increased to 75.58. The mathematical literacy levels showed improvement after applying Problem-Based Learning is also seen from the results of the t-test, where the calculated t is greater than the t-table, which is 7.53 more than 1.656.

When viewed by educational level, both junior high and senior high schools/vocational schools, the influence of Problem-Based Learning is equally high, although the magnitude varies slightly. The use of digital media such as GeoGebra and e-LKPD, along with authentic problem contexts, has been shown to strengthen mathematical literacy. Overall, Problem-Based Learning is effective in improving mathematical literacy at various levels, and its implementation needs to be continuously developed, taking into account learning design, technology integration, and teacher readiness for optimal and sustainable results.

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