

The Effectiveness of the Problem Based Learning Model in Enhancing Students' Mathematical Literacy at the Senior High School Level

A. Safwan Ibrahim Haz¹, Shahriani S^{2*}, Nurul Khofifah Amran³, Muthya Hanifa⁴, Rista Faradila⁵,
Lisnasari Andi Mattoliang⁶, Yulianti P⁷

^{1,2,3,4,5,6}Universitas Islam Negeri Alauddin Makassar, Indonesia

⁷Sekolah Menengah Atas Negeri 2 Sleman, Indonesia

shahriani2909@gmail.com

 <http://dx.doi.org/10.30595/alphamath.v11i2.28605>

ABSTRACT

This study examines the effectiveness of the Problem-Based Learning (PBL) model in improving students' mathematical literacy at the senior high school level. A quasi-experimental method with a pretest–posttest control group design was applied to two classes at SMAN 2 Sleman. Descriptive statistics showed that the experimental class experienced a substantial increase in mean scores from 56.25 to 88.50 with a standard deviation decreasing from 6.24 to 5.38, indicating more consistent learning outcomes. Meanwhile, the control class showed a lower improvement, with the mean rising from 55.75 to 76.00, and the standard deviation decreasing from 7.21 to 6.84. The N-Gain results further demonstrated the effectiveness of the PBL model, with the experimental group achieving an N-Gain score of 0.73 (high category) compared to 0.44 (medium category) in the control group. An independent samples t-test revealed no significant difference in the pretest ($\text{sig.} = 0.543 > 0.05$) but confirmed a significant difference in the posttest scores ($\text{sig.} = 0.000 < 0.05$). These findings indicate that PBL enhances key components of mathematical literacy such as reasoning, contextual understanding, and problem-solving because these abilities represent core competencies required to apply mathematics effectively in real-life situations. Therefore, PBL is shown to have a statistically significant impact on strengthening students' mathematical literacy as a whole.

Keywords: Problem Based Learning, Mathematical Literacy, Learning Effectiveness.

Received : October 30, 2025

Revised : November 22, 2025

Accepted : November 27, 2025

Introduction

Mathematics plays a central role in developing students' analytical and reasoning abilities, which are essential components of mathematical literacy. As stated by Maghfiroh et al. (2021), mathematics serves as a fundamental discipline that supports students in understanding and applying concepts across various fields. Through mathematics learning, students are expected to build conceptual understanding, strengthen logical reasoning, and apply mathematical ideas to real-life situations. This aligns with the view of Gusteti & Neviyarni (2022), who highlight that mathematics learning aims to cultivate logical, systematic, and creative thinking abilities that form the foundation of mathematical literacy.

However, mathematics instruction in schools continues to be dominated by procedural drills and teacher-centered approaches, which restrict students' opportunities to relate mathematical ideas to real-world contexts (Azzahra et al., 2024; Matondang et al., 2023). This situation leads to low mathematical literacy, as students find it difficult to interpret information, think mathematically, and effectively solve problems in real-life contexts (OECD, 2023; Hidayatulloh et al., 2025). As per PISA, mathematical literacy includes critical skills such as reasoning, contextual understanding, and problem-solving, enabling individuals to make decisions based on evidence.

According to the 2022 According to the Programme for International Student Assessment (PISA), Indonesia's results in mathematical literacy continue to fall short of the mean level of OECD countries (OECD, 2023). This situation shows that numerous students continue to have difficulty grasping and utilizing mathematical principles in practical scenarios. Consequently, it's essential to adopt innovative educational frameworks that encourage active participation from students, develop advanced thinking abilities, and consistently improve mathematical literacy. The starting state of mathematical literacy skills at SMAN 2 Sleman was still rated as moderate, shown by the average pretest score of 56.25 in the experimental group and 55.75 in the control group, with a considerable score range (45–70 and 40–72) and significant standard deviations (6.24 and 7.21), reflecting a disparity in abilities among the students. These results indicate that before the intervention, students still faced challenges with grasping contexts, analyzing information, and linking mathematical ideas to real-life scenarios.

An effective instructional approach for addressing these challenges is Problem-Based Learning (PBL), which starts the learning process with authentic issues and positions students as proactive problem solvers (Kiawati et al., 2023). The PBL model is a teaching method focused on students that initiates learning via genuine problems from the real world (Berlian et al., 2023). Through involving students in recognizing issues, assessing data, and formulating solutions, PBL systematically fosters aspects of mathematical literacy like reasoning, problem-solving, communication, teamwork, and reflective thought (Khoiryah & Nurmilah, 2024). In this process, learners cultivate analytical thinking, communication abilities, teamwork, and reflective practices, all of which are essential elements of mathematical literacy (Nisa et al., 2025). Moreover, PBL is in harmony with the Merdeka Curriculum that encourages competency-oriented education and situational problem-solving. (Putri et al., 2024). Earlier research

primarily investigated the effects of PBL on specific mathematical abilities or within narrow contexts, resulting in a lack of extensive proof concerning PBL's influence on overall mathematical literacy among senior high school students (Erria et al., 2023). Consequently, this study investigates the effectiveness of the Problem-Based Learning method in improving mathematical literacy among high school students, serving as a practical measure to strengthen adaptive, 21st-century, problem-solving focused education (Paloloang et al., 2021). Consequently, this study presents originality by incorporating PBL into a comprehensive mathematical literacy framework with indicators aligned to PISA, while evaluating its effectiveness in high school mathematics learning through empirical and statistical evidence that has not been extensively documented in prior research (Juliangkary et al., 2025).

This research intends to evaluate how effective the Problem-Based Learning model is in enhancing the mathematical literacy abilities of high school students. The anticipated outcome is that PBL can yield substantial and steady enhancements in students' skill to articulate, utilize, and analyze mathematics in practical scenarios, thus aiding in the evolution of adaptive learning in accordance with 21st-century skills. To accomplish this goal, the research utilized a quantitative method with a quasi-experimental framework, specifically a Nonequivalent Control Group Design, which included two classes as study samples. The experimental group was taught using the Problem-Based Learning approach, whereas the control group was instructed with traditional teaching techniques. Data regarding students' mathematical literacy abilities were gathered via a literacy assessment test and then analyzed statistically to identify notable differences in learning outcomes between the two groups.

Methods

This research uses a quantitative method featuring a quasi-experimental design that incorporates a control group with both pretest and posttest measures. The study's population included all students in the eleventh grade at SMAN 2 Sleman. The samples were chosen using a purposive sampling method, taking into account the similarity in students' academic traits and their previous mathematics learning experiences. Two classes were selected as the sample: one as the experimental group and the other serving as the control group. This sampling method was employed to guarantee that both groups possessed similar initial skills, thus reducing bias in the inferential statistical assessment. This design was chosen to investigate the impact of the Problem-Based Learning (PBL) method on improving students' mathematical literacy abilities. The study targeted all eleventh-grade students at SMA Negeri 2

Sleman, with the sample comprising two deliberately chosen classes: one identified as the experimental group implementing the PBL model and the other as the control group undergoing traditional teaching methods.

The research tool consisted of a mathematical literacy test in essay format, created based on the mathematical literacy indicators proposed by the OECD (2023), that includes the methods of creating, utilizing, and understanding. Before implementation, three experts evaluated the content validity of the instrument utilizing the Content Validity Ratio (CVR) method proposed by Lawshe (1975), while its reliability was examined through Cronbach's Alpha coefficient.

Research Procedure

The implementation of this study was carried out in three main stages, namely:

1. Preparation stage

At this point, the curriculum and educational resources were assessed to identify subjects appropriate for applying the PBL (Problem-Based Learning) model. Subsequently, educational tools were created, comprising the Lesson Plan, Student Worksheet, and mathematical literacy assessment. These instruments were subsequently assessed by three experts in mathematics education to determine the appropriateness of their content, construct, and language.

2. Implementation Stage

At this point, the curriculum and educational resources were assessed to identify subjects appropriate for applying the PBL (Problem-Based Learning) model. Subsequently, educational tools were created, comprising the Lesson Plan, Student Worksheet, and mathematical literacy assessment. These instruments were subsequently assessed by three experts in mathematics education to determine the appropriateness of their content, construct, and language. Instructional techniques in the experimental group were carried out utilizing the five essential steps of PBL, namely:

- a. Introducing students regarding the issue
- b. Organizing students to actively participate in the learning activities.
- c. Facilitating personal and collective inquiries
- d. Assisting students in creating and showcasing their findings.
- e. Reviewing and evaluating the issue resolution procedure

After all learning sessions were finished, both classes took a posttest using equivalent instruments to assess the improvement in mathematical literacy skills.

3. Data Analysis Stage

The pre-test and post-test administered in this study consisted of items that measured the same mathematical literacy indicators. Although the questions were not identical, they were equivalent in structure, cognitive demand, and coverage of the indicators. Using non-identical but equivalent items prevents the possibility of memorization effects and strengthens the internal validity of the study results. The equivalence was confirmed through expert validation and empirical testing procedures.

Data Analysis Technique

Employing the information collected in this study, A quantitative assessment was conducted to analyze the impact of implementing the Problem-Based Learning model on students' mathematical literacy skills. The assessment was carried out in multiple phases, namely:

1. Descriptive Analysis

A descriptive analysis was conducted to illustrate the characteristics of students' mathematical literacy skills before and after the learning intervention. The data presented consist of the average, highest, and lowest scores, as well as the typical variance for both the test and reference groups.

2. Assumption Tests For Analysis

Before conducting the hypothesis test, assumption tests were first performed, including tests for normality and homogeneity

- a. The Kolmogorov–Smirnov test was employed to assess normality procedure to verify that the dataset met the assumptions of a normal distribution.
- b. Levene's An examination was conducted to evaluate homogeneity, determining whether the variances of the experimental and control groups were equivalent.

Both tests were conducted using SPSS Statistics version 25.

3. Inferential Analysis

An Independent Samples t-test at a significance level of 0.05 was utilized to examine the differences in mathematical literacy enhancement between the experimental and control groups. The effectiveness of the Problem-Based Learning approach was subsequently evaluated utilizing the N-Gain Score with equation (1) (Hake, 1999).

$$N - Gain = \frac{(Skor_{post} - Skor_{pre})}{(Skor_{maks} - Skor_{pre})} \quad (1)$$

The N-Gain value was subsequently understood according to the criteria established by Hake (1999), specifically: elevated ($g \geq 0.7$), average ($0.3 \leq g < 0.7$), and minimal ($g < 0.3$). The Problem-Based Learning model is considered effective when the average N-Gain score falls within the medium or high range.

Result and Discussions

Result

This study aims to assess the impact of the Problem-Based Learning (PBL) method on the mathematical literacy skills of junior high school students. The study comprised two groups: one experimental class using the PBL approach and one control class receiving traditional teaching methods. The information was collected from a mathematical literacy evaluation conducted as a pretest and a posttest. A descriptive analysis was conducted to provide an overview of students' mathematical competency levels prior to and following the introduction of Problem Based Learning. The results include the minimum and maximum scores, the mean score, and the standard deviation for both the experimental and control group classes.

Table 1. Descriptive Statistics of Students' Mathematical Literacy Skills

Class	Test	Min Score	Max Score	Mean	Standard Deviation
Experiment	Pretest	45	70	56.25	6.24
Experiment	Posttest	75	95	88.50	5.38
Control	Pretest	40	72	55.75	7.21
Control	Posttest	60	85	76.00	6.84

Table 1, it is evident that the typical rise in mathematical literacy scores in the experimental class was 32.25 points, whereas the improvement in the control class was 20.25 points. Moreover, the decrease in the dispersion value for the experimental group suggests that the range of students' abilities narrowed after the PBL approach was implemented, reflecting greater consistency in individual learning outcomes.

The descriptive analysis showed that students in the experimental class experienced a greater improvement in mathematical literacy than those in the control class. The increase in mean scores, accompanied by a reduction in standard deviation, indicates not only an enhancement in overall performance but also a more evenly distributed learning outcome among students. In contrast, the control class showed a smaller increase with higher variability, suggesting that conventional instruction was less effective in supporting students consistently. These findings provide initial evidence that PBL encourages a more uniform and significant improvement in mathematical literacy across learners.

Before carrying out the hypothesis testing, the data were first subjected to normality and homogeneity assessments.

1. The Kolmogorov–Smirnov test yielded a significance level of $0.200 > 0.05$, showing that the data met the assumption of normality
2. Levene’s Test showed a significance value of 0.148 is greater than 0.05, suggesting that the data satisfied the homogeneity assumption.

Thus, the data meet the premises for performin inferential analysis using *T-test for Independent Samples*.

Table 2. N-Gain Evaluation Outcomes of Mathematical Literacy Abilities

Class	Pretest Mean	Posttest Mean	N-Gain	Category
Experiment	56.25	88.50	0.73	Tinggi
Control	55.75	76.00	0.44	Sedang

To evaluate an N-Gain assessment was performed to assess the effectiveness of the enhancement in mathematical literacy skills based on the following criteri Hake (1999). Table 2 indicates that the experimental group recorded a typical N-Gain of 0.73, putting it in the high range, whereas the control class had a typical N-Gain of 0.44, categorized as average. These results suggest that the The PBL model is more effective at improving mathematical literacy skills than the conventional learning approach. A separate t-test was conducted to assess whether the difference in educational results between the two groups was statistically significant. Table 3 displays the results of this analysis.

Table 3. Results of the Independent t-Test of Mathematical Literacy Skills

Test	t-Test	Significance	Description
Pretest	0.612	0.543	No Significant Difference
Posttest	4.731	0.000	There is a Significant Difference

According to Table 3, the pretest importance value was 0.543, that is more than 0.05, suggesting that the experimental and control classes did not differ significantly in their initial abilities. In contrast, the posttest significance value was $0.000 < 0.05$, indicating a notable distinction between the two groups following the intervention. It can be inferred that the Problem-Based Learning model effectively enhances students' mathematical literacy skills.

Discussions

Findings from this research suggest that utilizing the Problem-Based Learning (PBL) method significantly improves students' mathematical literacy skills. The

independent t-test results confirmed this finding, indicating a substantial difference in posttest scores between the experimental group and the control group ($\text{sig.} = 0.000 < 0.05$). Additionally, the N-Gain assessment indicated that the enhancement in mathematical literacy for the experimental group was rated as high (0.73), while the control group was deemed medium (0.44). These findings imply that the PBL approach is more efficient than traditional instruction in enhancing students' math abilities, consistent with previous studies (Kiawati et al. 2023; Listiawati et al. 2025).

These findings correspond with the studies of Berlian et al. (2023) and Khoiryah & Nurmilah (2024) who also reported that implementing the Problem-Based Learning approach greatly enhances students' mathematical proficiency by developing analytical reasoning and real-world solution-oriented abilities. This alignment is reflected in the present study, as the PBL group demonstrated significant improvements in reasoning, contextual understanding, and problem-solving skills, which match the competencies reported in previous research. Therefore, the results of this study not only support but also extend the existing evidence by showing that PBL effectively strengthens key components of mathematical literacy in the high school context.

The Problem-Based Learning model promotes active knowledge construction by having students solve contextual problems (Busdayu et al., 2023). PBL can improve analytical reasoning, communication, and the capacity to utilize ideas in real-life situations (Ahmad Gufron et al., 2025). This aligns with the findings of this study, where students who actively engaged in exploring problems developed a more profound and significant grasp of mathematical ideas. Consequently, learning focuses not only on procedural problem-solving but also on conceptual comprehension and the practical application of knowledge (Maslihah et al., 2021).

Each stage of the PBL model contributes directly to the development of mathematical literacy components as defined by OECD (2023). In the problem-orientation stage, students engage in the *formulating* process, translating contextual situations into mathematical representations. The information-gathering and investigation stage strengthens the employing process, in which students select and apply mathematical concepts to analyze data (Ambarwati & Ekawati, 2022). Group discussion and solution evaluation support the *interpreting* process, enabling students to explain and justify mathematical results within real-world contexts. This is supported by the findings of Mardiyah & Kusmaryono (2025), who reported that in the fourth phase of PBL, students present their solutions in the form of posters, graphs, or diagrams, interpret the mathematical outcomes, relate them back to the initial problem context, and receive feedback from peers. Finally, the reflection stage reinforces metacognitive

practices that help students evaluate their reasoning and connect mathematical concepts to authentic situations. Sari et al. (2022) provide empirical evidence that metacognitive skills in PBL enable students to monitor their problem-solving steps, recognize and correct errors, and link new information to their prior knowledge, thereby strengthening their reflective abilities. Thus, each step of the PBL model systematically enhances students' ability to formulate, employ, and interpret mathematics across meaningful contexts.

Furthermore, the efficiency of the PBL approach in enhancing components of mathematical literacy is supported by its approach of using practical issues as the foundation for the educational experience (Mukhlisin et al., 2023). By engaging in activities like problem identification, information analysis, and evidence-based problem-solving, students learn to link mathematical concepts with real-life situations (Lia & Safrina, 2025). This aligns with the is of mathematical literacy by OECD (2023) This approach highlights individuals' capacity to develop, apply, and analyze mathematics in various real-world situations. Therefore, implementing PBL can serve as a powerful approach to attain the objectives of mathematics education in the Merdeka Curriculum, particularly in fostering critical, reflective, and adaptive thinking skills (Pratiwi & Widjajanti, 2020; S. J. Putri & Prahani, 2025).

The results of this research further corroborate earlier studies carried out by Boye & Agyei (2023), which demonstrated that implementing PBL approach can improve students' mathematical literacy abilities through collaborative and reflective activities. In a similar vein, Muslih & Nirmala (2023) highlight that the A problem-centered learning method not just enhances conceptual comprehension but likewise promotes reasoning and decision-making based on evidence. Consequently, the findings of this study offer further empirical support that PBL is an effective instructional model for developing senior skills in mathematical literacy among high school students.

This research has several limitations, particularly the quasi-experimental design involving only two selected classes, which restricts the generalizability of the findings. The mathematical literacy test instrument also represents only certain aspects of literacy, so it does not fully capture students' overall abilities. Furthermore, the effectiveness of implementing Problem-Based Learning (PBL) is strongly influenced by teacher preparedness and the limited instructional time available. These limitations indicate that future research should involve more diverse samples and more comprehensive instruments, while practically highlighting the need for teacher training and better time management to ensure optimal PBL implementation. Despite these constraints, the findings show that learners acquire both theoretical comprehension and the capability to apply their knowledge to real-world problems

(Ihwan & Rusnilawati, 2025; Fitria et al., 2024), suggesting that PBL-based mathematics instruction can effectively enhance the quality of teaching and strengthen students' mathematical understanding.

Conclusion

The examination of the data shows that employing the Problem-Based Learning (PBL) approach significantly enhances the mathematical literacy abilities of senior high school students. This result aligns with earlier studies indicating that PBL improves mathematical literacy by engaging students in contextual problem-solving tasks. The independent samples t-test produced a p-value of $0.000 < 0.05$, demonstrating a significant difference between the experimental and control groups. The experimental group achieved a higher improvement with an N-Gain score of 0.73 (high category), compared to 0.44 (medium category) in the control group. These results indicate that PBL is more effective in strengthening components of mathematical literacy, particularly reasoning, representation, and contextual problem-solving. In conclusion, the Problem-Based Learning model is proven to be effective in enhancing mathematical literacy among senior high school students. Future studies are encouraged to apply the PBL model across various mathematical topics and with larger sample groups to further investigate its impact on students' higher-order thinking skills.

Acknowledgement

Appreciation is likewise given to the Department of Mathematics Education at UIN Alauddin Makassar and SMAN 2 Sleman.

Author's Declaration

- Author Contribution : Author 1: Conceptualization, Methodology, Data Curation, and Writing – Original Draft.
Author 2: Conceptualization, Methodology, Data Curation, and Writing – Original Draft.
Author 3: Conceptualization, Methodology, Data Curation, and Writing – Original Draft.
Author 4: Conceptualization, Methodology, Data Curation, and Writing – Original Draft.
Author 5: Conceptualization, Methodology, Data Curation, and Writing – Original Draft.
Author 6: Validation
Author 7: Validation
- Funding Statement : This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.
- Conflict of Interest : The authors declare no conflict of interest regarding the publication of this article.

Additional Information : Additional information related to this study is available from the corresponding author upon reasonable request.

References

- Ahmad Gufron, Isti Hidayah, Ardhi Prabowo, Wardono, & Scolastika Mariani. (2025). The Effectiveness of Problem-Based Learning in Enhancing Mathematical Literacy: A Systematic Meta-Analysis. *Jurnal Elemen*, 11(2), 483–501. <https://doi.org/10.29408/jel.v11i2.30002>
- Ambarwati, B. T., & Ekawati, R. (2022). Analisis Literasi Matematika Siswa dalam Menyelesaikan Soal Higher Order Thinking Skills (HOTS) Proporsi. *MATHEdunesa Jurnal Ilmiah Pendidikan Matematika*, 11(2). <https://doi.org/10.26740/mathedunesa.v11n2.p390-403>
- Azzahra, U., Arsih, F., & Alberida, H. (2024). Pengaruh Model Pembelajaran Project Based Learning Terhadap Keterampilan Berpikir Kreatif Peserta Didik Pada Pembelajaran Biologi: Literature Review. *BIOCHEPHY: Journal of Science Education*, 10(2), 156–161. <https://doi.org/10.22437/biodik.v10i2.33827>
- Banurea, R. D. U., Simanjuntak, R. E., Siagian, R., & Turnip, H. (2023). Perencanaan Pendidikan. *Pediaqu : Jurnal Pendidikan Sosial Dan Humaniora*, 2(1), 88–99.
- Berlian, M., Surya, E., & Khairani, N. (2023). Pengaruh Model Problem Based Learning Terhadap Kemampuan Pemecahan Masalah Matematika dan Self-Efficacy Siswa. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, 7(2), 1533–1544. <https://doi.org/10.31004/cendekia.v7i2.2291>
- Boye, E. S., & Agyei, D. D. (2023). Effectiveness of Problem-Based Learning Strategy in Improving Teaching and Learning of Mathematics for Pre-Service Teachers in Ghana. *Social Sciences and Humanities Open*, 7(1), 100453. <https://doi.org/10.1016/j.ssaho.2023.100453>
- Busdayu, Z. A., Rahmawati, N., Setiadi, D., Fkip, P. G., & Mataram, U. (2023). Penerapan Model Pembelajaran Problem Based Learning Meningkatkan Keterampilan Berpikir Tingkat Tinggi (HOTS). *Journal of Classroom Action Research*, 5 (4). <https://doi.org/10.29303/jcar.v5i4.5537>
- Erria, R., Buyung, Nirawati, R., & Paruntu, P. E. (2023). Pengaruh Problem Based Learning Terhadap Literasi Matematika. *Journal of Educational Review and Research*, 6(1), 78–85. <https://dx.doi.org/10.26737/jerr.v6i1.4690>
- Fitria, D., Asrizal, A., Dhanil, M., & Lufri, L. (2024). Impact of blended problem-based learning on students' 21st century skills on science learning: A meta-analysis. *International Journal of Education in Mathematics, Science, and Technology (IJEMST)*, 12(4), 1032- 1052. <https://doi.org/10.46328/ijemst.4080>
- Gusteti, Me. U., & Neviyarni. (2022). Pembelajaran Berdiferensiasi pada Pembelajaran Matematika di Kurikulum Merdeka. *Lebesgue: Jurnal Ilmiah Pendidikan*

- Matematika, Matematika Dan Statistika, 3(3), 170–184.
<https://doi.org/10.4324/9781003175735-15>
- Hake, R. R. (1999). Analyzing Change/Gain Scores. In Indiana University.
- Hidayatulloh, D. A., Alghar, M. Z., & Usman, M. R. (2025). Students' Mathematical Literacy in Solving Contextual Problems: A Review of the Perceived of Logical Mathematical Intelligence. 7(2), 150–165.
<https://doi.org/10.35438/inomatika.v7i2.498>
- Ihwan, A. Z., & Rusnilawati. (2025). Problem Based Learning Model with CRT Assisted by Augmented Reality to Improve Mathematics Learning Outcomes. 12, 82–97. <https://doi.org/10.23917/ppd.v12i1.10916>
- Juliangkary, E., Yuliyanti, S., & Pujilestari. (2025). Efektivitas LKPD Berbasis Problem Based Learning dalam Meningkatkan Literasi Matematis Siswa Sekolah Menengah. Jurnal Ilmiah Mandalika Education, 24(3).
<https://doi.org/10.36312/madu.v3i1.225>
- Khoiryah, L., & Nurmilah, R. (2024). Penerapan Model Pembelajaran Problem Based Learning Terhadap Kemampuan Literasi Matematis Siswa. Prosiding Seminar Nasional Pendidikan Matematika, Universitas Mulawarman, 4, 11–16.
- Kiawati, E. S., Junedi, B., & Tabrani, M. B. (2023). Penerapan Model Pembelajaran Berbasis Masalah Untuk Meningkatkan Kemampuan Literasi Matematis Siswa. Jurnal Cendekia: Jurnal Pendidikan Matematika, 7(3), 2465–2474. <https://doi.org/10.51878/science.v4i1.2907>
- Lawshe, C. H. (1975). a Quantitative Approach To Content Validity. Personnel Psychology, 28(4), 563–575. <https://doi.org/10.1111/j.1744-6570.1975.tb01393.x>
- Lia, L., & Safrina, K. (2025). Peningkatan Kemampuan Pemecahan Masalah Melalui Model Problem Based Learning pada Peserta Didik SMP/MTs. Numeracy, 12(1), 84–98. <https://doi.org/10.46244/numeracy.v12i1.3117>
- Listiawati, N., Wirda, Y., Zulkardi, & Riyanto, B. (2025). Bridging mathematics and communication: Implementing realistic mathematics education principles for skill development. Journal on Mathematics Education, 16, 729–752.
<https://doi.org/10.22342/jme.v16i2.pp729-752>
- Maghfiroh, F. L., Amin, S. M., Ibrahim, M., & Hartatik, S. (2021). Keefektifan Pendekatan Pendidikan Matematika Realistik Indonesia terhadap Kemampuan Literasi Numerasi Siswa di Sekolah Dasar. Jurnal Basicedu, 5(5), 3342–3351.
<https://doi.org/10.31004/basicedu.v5i5.1341>
- Mardiyah, I., & Kusmaryono, I. (2025). Penerapan PBL Berbasis CRT Berbantuan Kahoot untuk Meningkatkan Literasi Matematika. Jurnal Jendela Pendidikan, 5(02), 338–345. <https://doi.org/10.57008/jjp.v5i02.1350>
- Maslihah, S., Waluya, S. B., Rochmad, Kartono, Karomah, N., & K, I. (2021). Increasing mathematical literacy ability and learning independence through problem-based

- learning model with realistic mathematic education approach. <https://doi.org/10.1088/1742-6596/1918/4/042123>
- Matondang, K., Saragih, R. M. B., & Daulay, L. A. (2023). Analisis Kemampuan Literasi Matematika Siswa. *OMEGA: Jurnal Keilmuan Pendidikan Matematika*, 2(3), 142–148. <https://doi.org/10.47662/jkpm.v2i3.595>
- Mukhlisin, L., Hayyi, A., Zuhdiniati, & Murcahyanto, H. (2023). Pengaruh Model Pembelajaran Berbasis Masalah Terhadap Kemampuan Literasi, Berfikir Kritis Pada Mata Pelajaran Bahasa Indonesia. *Literatur: Jurnal Bahasa, Sastra Dan Pengajaran*, 4, 22–36. <https://doi.org/10.31539/literatur.v4i1.7725>
- Musliah, L., & Nirmala, S. D. (2023). Keefektifan Model Pembelajaran Problem Based Learning (PBL) terhadap Kemampuan Literasi dan Numerasi Peserta Didik di Sekolah Dasar. *Jurnal Basicedu*, 7(1), 1-10. <https://doi.org/10.31004/basicedu.v7i1.4106>
- Nisa, I., Ardanik, & Hatip, A. (2025). Students' Critical Thinking and Collaborative Skills Through the Problem Based Collaborative, and Learning Model. *Jurnal Pendidikan Matematika*, 16(2), 129–142. <https://doi.org/10.36709/jpm.v16i2.301>
- Nyoman, D. W. A., Sadri, N. W., & Temaja, I. G. B. W. B. (2025). Character Education in 21st Century Learning in Indonesia. *West Science Social and Humanities Studies*, April. <https://doi.org/10.58812/wsshs.v3i04.1814>
- OECD. (2023). Pisa 2022 Results The State of Learning and Equity in Education. In Factsheets: Vol. I. https://www.oecd-ilibrary.org/education/pisa-2022-results-volume-i_53f23881-en%0Ahttps://www.oecd.org/publication/pisa-2022-results/country-notes/germany-1a2cf137/
- Paloloang, M. F. B., Juandi, D., Tamur, M., Paloloang, B., & Adem, A. M. G. (2021). Meta Analisis: Pengaruh Problem-Based Learning Terhadap Kemampuan Literasi Matematis Siswa Di Indonesia Tujuh Tahun Terakhir. *Aksioma : Jurnal Program Studi Pendidikan Matematika*, 9(4), 851-864. <https://doi.org/10.24127/ajpm.v9i4.3049>
- Pratiwi, S. A., & Widjajanti, D. B. (2020). Contextual problem in mathematical problem solving: core ability in Realistic Mathematics Education. *Journal of Physics*, 1613 012018, 1-7. <https://doi.org/10.1088/1742-6596/1613/1/012018>
- Putri, D. E. N., Maulana, M., & Irawati, R. (2024). Pengaruh Model Problem-based Learning terhadap Kemampuan Pemecahan Masalah Matematis Siswa. *Ideguru: Jurnal Karya Ilmiah Guru*, 9(3), 1797–1804. <https://doi.org/10.51169/ideguru.v9i3.1307>
- Putri, S. J., & Prahani, B. K. (2025). Enhancing students' critical thinking skills through mobile technology : An analysis of problem-based learning implementation in heat material instruction. 5(1), 1242–1253. <https://doi.org/10.25082/AMLER.2025.01.001>

- Ramadhani, T., Widiyanta, D., Sumayana, Y., Santoso, R. Y., Agustin, P. D., & Amin, A. (2024). The Role of Character Education In Forming Ethical and Responsible Students. *International Journal Of Graduate Of Islamic Education*, 5(2), 110-124. <https://doi.org/10.37567/ijgie.v5i2.3064>
- Sari, Y. E., Permatasari, R., & Saputro, E. F. H. (2022). Efektivitas Model Problem Based Learning (PBL) pada Keterampilan Metakognisi Siswa. *Quantum: Jurnal Pembelajaran IPA dan Aplikasinya*, 2(1), 12–22. <https://doi.org/10.46368/qjpia.v2i1.730>