Journal of Mathematics Instruction, Social Research and Opinion
Vol. 5, No. 2, June 2026, pp. 1469 – 1479, https://doi.org/10.58421/misro.v5i2.1401
ISSN 2962-7842

Application of The Problem-Based Learning Model to Improve Mathematical Communication Ability of Senior High School Students

Silmi Ghaida[1], Al Jupri[2]
[1,2]Universitas Pendidikan Indonesia, Indonesia

Article Info

Article history:

Received 2026-04-03
Revised 2026-04-30
Accepted 2026-05-06

Keywords:

Learning Achievement
Mathematical Communication
Mathematics Education
Problem-Based Learning
Secondary School Students

ABSTRACT

Mathematical communication is an important component of mathematics learning, yet many students in Indonesia still have difficulty expressing mathematical ideas clearly. This study aimed to examine whether students taught using the Problem-Based Learning (PBL) model achieve better mathematical communication skills and greater improvement than those taught using conventional instruction. This study used a quantitative approach with a quasi-experimental design, specifically a pretest–posttest non-equivalent control group design. The participants were 68 tenth-grade students from a senior high school in Bandung, divided into an experimental class and a control class using purposive sampling. Data were collected through written tests and observation sheets. The data were analyzed using the Mann–Whitney test and n-gain scores. The results showed that the experimental class had a higher posttest mean score than the control class, with a mean difference of 12.00 points. Statistical analysis indicated a significant difference between the two groups ($p = 0.0315 < 0.05$). In terms of improvement, the experimental class achieved a higher n-gain (0.53, medium category) compared to the control class (0.37, medium category), with a significant difference ($p = 0.008 < 0.05$). These findings indicate that the PBL model is effective in improving students' mathematical communication skills and can serve as an alternative learning strategy in mathematics classrooms.

Corresponding Author:

Al Jupri
Universitas Pendidikan Indonesia
Email: aljupri@upi.edu

1. INTRODUCTION

Mathematics is an essential subject in school learning and plays an important role in everyday life [1]–[7]. In mathematics education, students are expected to master several key competencies, including problem-solving, mathematical communication, reasoning, connections, and representation [8]. These competencies are interconnected and support students in developing a comprehensive understanding of mathematics. When students master these abilities, they are more likely to become active learners and apply mathematical concepts in various contexts.

Among these competencies, mathematical communication is a fundamental aspect that needs special attention. Mathematical communication helps students organize their thinking and express ideas clearly using appropriate mathematical language [9], [10]. It also reflects how well students understand concepts and enables teachers to assess students' thinking processes and provide appropriate feedback. Therefore, mathematical communication is not only a learning outcome but also a process that supports meaningful learning.

In line with this, the Ministry of Education emphasizes that mathematical communication is one of the main objectives of mathematics learning at the senior high school level [11]. However, there is still a gap between these expectations and actual classroom conditions. Many students have difficulty expressing mathematical ideas, both orally and in writing, suggesting that their mathematical communication skills have not developed optimally.

Previous studies have consistently shown that students' mathematical communication skills in Indonesia remain relatively low [12]–[16]. Students often struggle to connect concepts and explain their reasoning when solving problems [17]. This condition is influenced by several factors, including low student participation and the dominance of teacher-centered learning approaches [18]–[20]. As a result, learning processes have not fully supported the development of students' communication skills. This situation highlights the need for more effective and student-centered learning strategies.

To address this issue, the government has implemented curriculum reforms that emphasize student-centered learning, such as the 2013 Curriculum and the Merdeka Curriculum [11], [21]. These curricula recommend a scientific approach that involves observing, questioning, collecting information, associating, and communicating [11]. Research shows that this approach can improve students' interest and engagement in learning [22]. However, its implementation still requires appropriate learning models that can actively involve students.

One learning model that aligns with the scientific approach is Problem-Based Learning (PBL). PBL is a student-centered model that uses real-life problems as a starting point for learning [23], [24]. Through PBL, students work collaboratively to investigate problems, develop solutions, and present their findings. This process encourages critical thinking and enhances students' communication skills through discussion and presentation activities [23], [25]. Therefore, PBL has the potential to improve students' mathematical communication ability.

Several studies have shown that PBL can enhance students' learning engagement and higher-order thinking skills. However, most previous research has focused on general mathematical abilities or different subject materials. There is still limited research examining the effectiveness of PBL in improving mathematical communication skills in two-variable linear inequality systems at the senior high school level. This indicates a clear research gap that needs further investigation.

Based on this gap, this study aims to examine whether students' achievement and improvement in mathematical communication ability, when taught using the Problem-Based Learning model, are better than those taught using conventional instruction. The results of this study are expected to contribute to the development of more effective mathematics learning strategies, particularly in improving students' mathematical communication skills.

2. METHOD

2.1. Research Design

This study used a quantitative, quasi-experimental design. The design applied was a pretest–Posttest non-equivalent control group design. The experimental class was taught using the Problem-Based Learning (PBL) model, while the control class received conventional learning. Both classes were taught using a scientific approach, as the school implemented the Merdeka Curriculum. The purpose of this study was to examine the effect of the PBL model on students' mathematical communication ability, particularly on the topic of two-variable linear inequality systems.

The study's research design is presented in detail below.

$$O \quad X_1 \quad O$$
$$- - - - - -$$
$$O \quad X_2 \quad O$$

Source: Lestari & Yudhanegara [15]

Information:

O : Pretest and posttest of the experimental class and the control class.
X_1 : Treatment with the Problem-Based Learning model in the experimental class.
X_2 : Treatment with the conventional learning model in the control class.
$- -$: Students were not randomly selected.

2.2. Population and Sample Study

The population of this study consisted of all tenth-grade students in a senior high school in Bandung. The sample was selected using purposive sampling based on the following criteria:

(1) classes taught by the same mathematics teacher,
(2) classes with relatively similar academic ability based on previous mathematics scores and
(3) classes that had studied prerequisite materials related to the topic.

Based on these criteria, two classes were selected, each consisting of 34 students. One class was assigned as the experimental group, and the other as the control group. The study was conducted from April to May in the even semester of the 2023/2024 academic year.

2.3. Data Collection Instruments and Techniques

This investigation mobilized a bifurcated instrumentation schema: evaluative (test-based) and non-evaluative apparatuses. The test instrument materialized as three validated descriptive items centered upon the system of linear inequalities in two variables. These instruments were administered in a pre-intervention (Pretest) and post-intervention (Posttest) sequence to calibrate both the attainment and the progressive augmentation of students' mathematical communicative competence. To quantify the escalation of this competence, analytical procedures were subsequently applied to the differential-score configurations. The n_gain formula was used as follows.

$$n_{gain} = \frac{posttest\ score - pretest\ score}{SMI - pretest\ score} \qquad 1)$$

Source: Lestari & Yudhanegara [15]
Information:
n gain : Normalized gain
SMI : Ideal maximum score

The criteria for interpreting the n_gain value according to Lestari & Yudhanegara [15] are as follows Table 1.

Table 1. Criteria of n_gain

N_gain	Criteria
$n_{gain} \geq 0{,}70$	High
$0{,}30 < n_{gain} < 0{,}70$	Middle
$n_{gain} \leq 0{,}30$	Low

Source: Lestari & Yudhanegara [15]

The non-test instrumentation consisted of structured observational protocols and systematic recording sheets that delineated both teacher and student enactments throughout the instructional continuum, designed to scrutinize the fidelity and sequential actualization of each procedural phase embedded in the Problem-Based Learning (PBL) architecture in experimental classes.

2.4. Data Analysis Techniques

Data analysis was conducted using pretest, posttest, and n-gain scores. Before hypothesis testing, prerequisite tests were carried out, including normality and homogeneity tests. The normality test used the Shapiro–Wilk test because the sample size was less than 50, while the homogeneity test used Levene's test. If the data were normally distributed and homogeneous, the independent-samples t-test was used for hypothesis testing. However, if these assumptions were not met, the Mann–Whitney test was used as a non-parametric alternative. The analysis was conducted in two stages. First, the posttest scores were analyzed to assess students' achievement in mathematical communication. Second, the n-gain scores were analyzed to determine improvements in students' abilities. Data from observation sheets were analyzed descriptively by calculating the percentage of implemented learning activities. This analysis was used to evaluate the implementation of the Problem-Based Learning model in the classroom.

3. RESULTS AND DISCUSSION

3.1. Results

The empirical substrate of this investigation was extracted from evaluative apparatuses, specifically the pre-intervention and post-intervention score matrices derived from both the experimental and control cohorts. The resultant pretest–posttest performances, together with the computed n-gain indices derived from those score differences, are presented in Table 2 hereunder.

Table 2. Statistical Results: Descriptive Data Pretest, Posttest, and N_gain

Class	N	Pretest		Posttest		N_gain	
		Average	STD	Average	STD	Average	Category of Improvement
Experiment	34	19.53	10.29	60.65	22.13	0.53	Middle
Control	34	21.41	14.33	48.65	26.98	0.37	Middle

The dataset presented in Table 2 comprises the pretest and posttest scores for both experimental and control cohorts, each calibrated to a ceiling of 100. Furthermore, the n-gain indices were algorithmically derived from the differential interplay between the pretest and posttest attainments. The tabular exposition reveals that the control cohort's mean pretest score marginally eclipses that of the experimental cohort, with a negligible discrepancy of 1.88—an infinitesimal divergence suggesting parity in baseline mathematical communicative competence across the two groups. Conversely, Table 2 delineates a pronounced posttest asymmetry: the experimental cohort surpasses the control cohort by a substantive margin of 12.00 points. Such a considerable differential indicates that the mathematical communicative proficiency of students in the experimental group demonstrably exceeds that of their control counterparts.

The evidentiary metrics used to assess students' attainment of mathematical communicative competence comprise the pretest and posttest score arrays. The outcomes of the Shapiro–Wilk normality diagnostics applied to the pretest and posttest distributions of both the experimental and control cohorts are presented in Table 3 below.

Table 3. Results of the Normality Test of Pretest and Posttest Data

Tests of Normality (Shapiro-Wilk)					
	Sample Class	Statistics	df	Sig.	Information
Pretest	Experiment	0.944	34	0.083	Normally distributed
	Control	0.922	34	0.018	Not normally distributed
Posttest	Experiment	0.929	34	0.029	Not normally distributed
	Control	0.902	34	0.005	Not normally distributed

Based on Table 3, the normality test results in IBM SPSS Statistics 25 indicate that the Sig. value pretest of the experimental class is > 0.05, while the Sig. The value of the other is < 0.05. We can conclude that the experimental class's pretest score data emanates from a Gaussian-distributed population, whereas the remaining dataset originates from distributions that deviate from normality.

The Mann–Whitney non-parametric procedure will be applied to the pretest score distributions of both cohorts to determine whether the mean baseline mathematical communicative competence of students in the experimental and control constellations differs in a statistically significant manner. The hypothesis in this test is as follows.

$H_0 : \mu_1 \leq \mu_2$ (No significant difference in the average initial mathematical communication ability between students in the experimental and control classes.)

$H_1 : \mu_1 > \mu_2$ (Significant difference in the average initial mathematical communication ability between students in the experimental and control classes.)

The significance level used is 5% ($\alpha = 0{,}05$) with the following test criteria.

Should the Sig. coefficient be ≥ α = 0.05, the null hypothesis (H_0) is upheld; conversely, if the Sig. value falls below α = 0.05, H_0 is consequently repudiated. The inferential outcomes of the Mann–Whitney non-parametric analysis applied to the pretest score distributions of the experimental and control cohorts are exhibited in Table 4 below.

Table 4. Results of the Mann-Whitney Pretest Data Test

Test Statistics	
	Pretest
Mann-Whitney U	519,500
Wilcoxon W	1114.500
Z	-0.719
Asymp. Sig. (2-tailed)	0.427

Based on Table 4, the results of the Mann-Whitney test using IBM Statistics 25 Software show that the $Sig\, value. (2 - tailed) = 0.427 > \alpha = 0.05$, then H_0 it is accepted. There is no significant difference in the average initial mathematical communication ability between students in the experimental and control classes.

Furthermore, the Mann-Whitney test will be conducted on the Posttest scores of both classes to ascertain whether the consummative stratum of students' mathematical communicative attainment within the experimental cohort demonstrably transcends, in statistically consequential magnitude, that of the control assemblage. The hypothesis in this test is as follows.

$\mathrm{H}_0 : \mu_1 \leq \mu_2$ (The culminative manifestation of students' mathematical communicative attainment within the experimental cohort did not exhibit a statistically consequential elevation relative to that observed in the control cohort)

$\mathrm{H}_1 : \mu_1 > \mu_2$ (The apical attainment of students' mathematical communicative competence in the experimental cohort registered a statistically salient ascendancy over that of their counterparts in the control cohort.)

The significance level used is 5% ($\alpha = 0{,}05$) with the following test criteria.

In the event that the Sig. magnitude attains or exceeds the threshold α = 0.05, the null postulate (H_0) is sustained; contrarily, should the Sig. coefficient descend beneath α = 0.05, H_0 is consequently nullified. The inferential yield of the Mann–Whitney non-parametric test applied to the posttest score distributions of the experimental and control cohorts is presented in Table 5 below.

Table 5. Results of the Mann-Whitney Test of Posttest Data

Test Statistics	Posttest
Mann-Whitney U	426,500
Wilcoxon W	1021.500
Z	-1,860
Asymp. Sig. (2-tailed)	0.063

Based on Table 5, the Mann-Whitney test results using IBM Statistics 25 Software show that the $Sig. = \frac{0.063}{2} = 0.0315 < \alpha = 0.05$, then H_0 is rejected. This means that students' mathematical communication skills in the experimental class are significantly higher than in the control class.

Subsequent to the ritualistic traversal of prerequisite diagnostics and inferential adjudications imposed upon the pretest and posttest matrices of both experimental and control constellations, an analogous statistical inquisition is enacted upon the n-gain magnitude. This procedural reiteration is orchestrated to interrogate whether the ascensional gradient of mathematical communicative prowess within the experimental enclave eclipses, in a statistically consequential manner, that of its control analog. The Shapiro–Wilk normality test applied to the n-gain distributions of the bifurcated cohorts yields the results summarized in the ensuing Table 6.

Table 6. Results of the Normality Test of N_gain Data

Tests of Normality (Shapiro-Wilk)	Sample Class	Statistics	df	Sig.	Information
N_gain	Experiment	0.935	34	0.043	Not normally distributed
	Control	0.878	34	0.001	Not normally distributed

Anchored in the exposition of Table 6, the normality diagnostics executed via IBM Statistics 25 divulge that the n-gain distributions of both the experimental and control cohorts deviate from Gaussian conformity. Consequently, a Mann–Whitney non-parametric inferential procedure is administered to the respective n-gain aggregates to ascertain whether the amplification of mathematical communicative competence within the experimental assemblage significantly surpasses that observed in the control counterpart. The hypothesis in this test is as follows.

$H_0 : \mu_1 \leq \mu_2$ (The escalation of students' mathematical communicative capacity within the experimental cohort did not attain a statistically superior magnitude relative to that manifested by the control cohort)

$H_1 : \mu_1 > \mu_2$ (The augmentation of students' mathematical communicative proficiency in the experimental cohort manifested a statistically pronounced superiority over that observed within the control cohort.)

The significance level used is 5% ($\alpha = 0{,}05$) with the following test criteria.

Should the Sig. coefficient be ≥ α = 0.05, the null hypothesis (H_0) is retained. Conversely, if the Sig. coefficient is < α = 0.05, H_0 is repudiated. The outcomes of the Mann–Whitney non-parametric test applied to the posttest distributions of the experimental and control cohorts are presented in the Table. 7 below.

Table 7. Results of the Mann-Whitney Test of N_gain Data

Test Statistics	N_gain
Mann-Whitney U	381,000
Wilcoxon W	976,000
Z	-2.417
Asymp. Sig. (2-tailed)	0.016

Based on Table 7, the Mann-Whitney test results using IBM Statistics 25 Software show that the $Sig. = \frac{0.016}{2} = 0.008 < \alpha = 0.05$, then H_0 It is rejected. This means that students' improvement in mathematical communication ability in the experimental class is significantly greater than that in the control class.

The analysis of non-test instrument data was based on the observers' written notes on the observation sheet. The summary of the observer's observations is shown in Table 8 below.

Table 8. Summary of The Observer's Observations

Activity	2nd meeting	3rd meeting	Percentage
Introduction (5)	5	5	100%
Main (8)	8	8	100%
Closing (5)	4	5	90%

Based on Table 8, the results on the observation sheet showed that the introduction and main activities were 100% well done. During the closing activities, only 90% of the activities were carried out from the 2 learning meetings. However, this figure is very good because only 1 point was not implemented, namely in the section “The teacher tells the material to be learned at the next meeting”.

3.2. Discussion

This study examined the effect of the Problem-Based Learning (PBL) model on students’ mathematical communication ability by comparing experimental and control groups. Both groups were taught using a scientific approach, but differed in the learning model applied. The findings provide important insights into both the effectiveness of PBL and its implications for classroom practice.

The analysis of pretest data showed no significant difference in students’ initial mathematical communication ability between the two groups. The small mean difference (1.88) and the Mann–Whitney test result (Sig. = 0.472 > 0.05) indicate that both groups had comparable starting points. This strengthens the internal validity of the study, as the differences found in the posttest and n-gain can be attributed more confidently to the treatment rather than initial ability differences.

After the intervention, the experimental group demonstrated higher mathematical communication ability than the control group. The difference in Posttest mean scores (12.00 points) and the Mann–Whitney result (Sig. = 0.0315 < 0.05) confirm that the PBL model significantly improves students’ achievement. From a pedagogical perspective, this result suggests that learning environments that emphasize problem-solving, discussion, and active participation can better support students in expressing mathematical ideas. Through PBL, students not only solve problems but also explain their reasoning, thereby strengthening their communication skills.

This finding aligns with previous studies that highlight the effectiveness of PBL in improving mathematical communication ability [13], [21]. The collaborative nature of PBL encourages students to articulate their ideas, respond to peers, and construct shared understanding. These processes are essential for developing both written and oral mathematical communication. In addition, the use of contextual problems in PBL helps students connect abstract concepts to real-life situations, making it easier for them to express their reasoning meaningfully.

However, not all studies fully support PBL's superiority. Some research has found that student-centered models, including PBL, may not produce significantly better results than conventional methods when students are not accustomed to active learning or when classroom management is less effective. In such cases, students may struggle to participate in discussions or rely too heavily on more dominant peers. This suggests that PBL's effectiveness depends on proper implementation, including teacher guidance, group organization, and students’ readiness to engage in active learning.

The improvement analysis using n-gain scores further supports the effectiveness of PBL. The experimental group achieved a moderate improvement (0.53), which was higher than the control group (0.37), with a significant difference (Sig. = 0.008 < 0.05). This indicates that PBL not only improves achievement but also enhances students’ learning progress. Pedagogically, this implies that continuous engagement in problem-solving activities helps students gradually develop their ability to communicate mathematical ideas more clearly and systematically.

The results of classroom observations also reinforce these findings. The implementation of PBL was effective, with 100% of the introduction and core activities completed and 90% of the closing activities implemented. This indicates that the teacher was able to facilitate learning according to the PBL stages, including presenting problems, guiding discussions, and encouraging students to present their work. Effective implementation is a key factor in ensuring PBL achieves its intended outcomes.

Despite these positive findings, this study has several limitations. First, the sample size was relatively small, involving only two classes with a total of 68 students. This limits the generalizability of the results. Second, the study was conducted in a single school, so the findings may not generalize to other school contexts or student characteristics. Third, the intervention was relatively short, which may not fully capture the long-term impact of the PBL model on students’ mathematical communication skills.

Given these limitations, future research should use larger samples across multiple schools to improve generalizability. In addition, longer intervention periods and the inclusion of qualitative data, such as interviews or classroom discourse analysis, would provide deeper insights into how students develop mathematical communication skills through PBL.

4. CONCLUSION

This study found that students taught using the Problem-Based Learning (PBL) model achieved higher mathematical communication skills than those who received conventional instruction within a scientific approach. In addition, students' improvement in mathematical communication ability in the PBL class was significantly greater than in the control class. These findings indicate that PBL is effective not only in improving students' achievement but also in enhancing their learning progress.

From a practical perspective, the results suggest that the PBL model can be an effective alternative for mathematics instruction, especially for developing students' mathematical communication skills. Teachers are encouraged to design learning activities that involve real-world problems, group discussions, and student presentations, as these elements can help students express and organize their mathematical ideas more clearly. Proper implementation of PBL, including structured guidance and active student engagement, is essential to achieve optimal results.

However, this study is limited by the small sample size and its focus on a single school context. Therefore, future research is recommended to involve larger and more diverse samples across different schools or regions to improve the generalizability of the findings. Further studies may also employ mixed-methods approaches to explore students' communication processes in greater depth, extend the intervention duration, and examine the effectiveness of PBL across different mathematical topics and educational levels.

REFERENCES

[1] Amin, N. F., Garancang, S., & Abunawas, K. Konsep Umum Populasi dan Sampel dalam Penelitian. *Jurnal Pilar*, *14*(1), 15–31, 2023.

[2] Aminah, S., Wijaya, T. T., & Yuspriyati, D. Analisis Kemampuan Komunikasi Matematis Siswa Kelas VIII Pada Materi Himpunan. *Journal Cendekia: Jurnal Pendidikan Matematika*, *1*(1), 15–22, 2018. https://doi.org/10.31004/cendekia.v2i1.29

[3] Ardianti, R., Sujarwanto, E., & Surahman, E. *Problem-based Learning: Apa dan Bagaimana*. *3*(1), 27–35, 2021. https://doi.org/10.37058/diffraction.v3i1.4416

[4] Dina, Z. H., Ikhsan, M., & Hajidin. The Improvement of Communication and Mathematical Disposition Abilities through Discovery Learning Model in Junior High School. *JRAMathEdu: Journal of Research and Advances in Mathematics Education*, *4*(1), 11–22, 2019. https://doi.org/10.23917/jramathedu.v4i1.6824

[5] Elfareta, N. J., & Murtiyasa, B. Analisis Kemampuan Komunikasi Matematis Materi Sistem Persamaan Linear Dua Variabel dengan Penerapan Teori Burner. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *11*(3), 2523–2532, 2022. https://doi.org/10.24127/ajpm.v11i3.5681

[6] Fauzie, Sofiyan, & Zaki, M. Penerapan Pendekatan Saintifik Untuk Meningkatkan Kemampuan Komunikasi Matematis Siswa SMA Negeri 4 Langsa. *Jurnal Dimensi Matematika*, *2*(2), 112–117, 2019. https://ejurnalunsam.id/index.php/JDM/article/view/1880

[7] Fitriani, R. N., & Pujiastuti, H. Pengaruh Self-Efficacy Terhadap Hasil Belajar Matematika. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, *05*(03), 2793–2801, 2021. https://doi.org/10.31004/cendekia.v5i3.803

[8] Ginting, I. R. F., & Sutirna. Analisis Kemampuan Pemahaman Konsep Matematis Pada Materi Sistem Persamaan Linear Dua Variabel. *MAJU*, *8*(1), 350–357, 2021.

[9] Hafidloh, A., Coesamin, M., & Widyastuti. Pengaruh Model Problem Based Learning Terhadap Kemampuan Komunikasi Matematis Siswa. *Jurnal Pendidikan Matematika*, *8*(3), 182–192, 2020.

[10] Hariati, M. E., Sinaga, B., & Mukhtar. Analisis Kesulitan Komunikasi Matematis Siswa Dalam Penerapan Model Pembelajaran Think Pair Share. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, *06*(01), 702–709, 2022. https://doi.org/10.31004/cendekia.v6i1.1228

[11] Jannah, N., Wadi, H., Malik, I., & Masyhuri. Implementasi Kurikulum Merdeka Dalam Mengintegrasikan Kemampuan HOTS dan Scientific Approach Pada Mata Pelajaran Sosiologi di MAN 2 Mataram. *Jurnal*

Ilmiah Profesi Pendidikan, *9*(4), 2442–2447, 2024. https://doi.org/10.29303/jipp.v9i4.2795

[12] Kemendikbudristek. 10. CP Matematika. In *Capaian Pembelajaran Mata Pelajaran Matematika Fase A - Fase F Untuk SD/MI/Program Paket A, SMP/MTs/Program Paket B, dan SMA/MA/Program Paket C*. 2022.

[13] Layliyyah, R., Wisudaningsih, E. T., & Rahayu, E. Pengaruh Model Pembelajaran Problem Based Learning Terhadap Kemampuan Komunikasi Matematis Siswa Kelas VII. *Jurnal Pendidikan Dan Konseling*, *4*(4), 345–351. 2022. https://doi.org/10.31004/jpdk.v4i4.5231

[14] Lea, Mantili, T. S., & Christin, E. Analisis Kemampuan Pemahaman Matematis Siswa pada Materi Turunan Fungsi Kelas XI Sma. *JUWARA: Jurnal Wawasan Dan Aksara*, *2*(1)., 2022. https://doi.org/10.58740/juwara.v2i1.35

[15] Lestari, & Yudhanegara, M. R. *Penelitian Pendidikan Matematika*. Bandung: PT Refika Aditama. 2017.

[16] Nainggolan, W. A., Sipahutar, M., Ramadhani, N. A., Thania, O. E., & Tanjung, I. F. Penerapan Model Pembelajaran Problem Based Learning dalam Meningkatkan Pemahaman Konsep Siswa Pada Materi Genetika di MAS 1 Yaspi Labuhan Deli. *Biodik*, *9*(1), 79–86, 2023. https://doi.org/10.22437/bio.v9i1.19206

[17] NCTM. *Principles and Standards for School Mathematics*. USA: The National Council of Teachers of Mathematics, Inc. 2000.

[18] Ningsih, A. R., Rohantizani, & Marhami. Peningkatan Kemampuan Komunikasi Matematis Siswa Melalui Pembelajaran Problem Based Learning (PBL) Pada Materi Sistem Persamaan Linear Dua Variabel di Kelas X SMK Negeri 1 Dewantara. *Ar-Riyadhiyyat: Jurnal Pendidikan Matematika*, *2*(1), 19–26, 2021. https://doi.org/10.47766/arriyadhiyyat.v2i1.1397

[19] Oktoviani, V., Widoyani, W. L., & Ferdianto, F. Analisis Kemampuan Pemahaman Matematis Siswa SMP pada Materi Sistem Persamaan Linear Dua Variabel. *Edumatica*, *09*, 2019. https://doi.org/10.22437/edumatica.v9i1.6346

[20] Peraturan Menteri Pendidikan Dan Kebudayaan Nomor 103 Tahun 2014 Tentang Pembelajaran Pada Pendidikan Dasar Dan Pendidikan Menengah (2014).

[21] Rahmalia, R., Hajidin, & Ansari, B. Peningkatan Kemampuan Komunikasi Matematis dan Disposisi Matematis Siswa SMP Melalui Model Problem Based Learning. *Jurnal Numeracy*, *7*(1), 137–149, 2020. https://doi.org/10.46244/numeracy.v7i1.1038

[22] Rahmawati, N. S., Bungsu, T. K., Islamiah, I. D., & Setiawan, W. Analisis Minat Belajar Siswa MA Al-Mubarok Melalui Pendekatan Saintifik Berbantuan Geogebra Pada Materi Statistika Dasar. *Journal On Education*, *01*(03), 386–395, 2019. https://doi.org/10.31004/joe.v1i3.180

[23] Refwalu, M., Mataheru, W., & Laamena, C. M. Komunikasi Matematis Peserta Didik SMP dalam Memecahkan Masalah Sistem Persamaan Linear Dua Variabel. *JNPM (Jurnal Nasional Pendidikan Matematika)*, *6*(4), 690, 2022. https://doi.org/10.33603/jnpm.v6i4.7154

[24] Sari, N. N., Kurniawati, N., & Wijaka, R. N. Deskripsi Kemampuan Komunikasi Matematis Siswa pada Materi Sistem Persamaan Linear Dua Variabel. *Jurnal Pendidikan Matematika Dan Sains*, *10*(1), 22–28, 2022. https://doi.org/10.21831/jpms.v10i1.39364

[25] Siswadi, Saragih, R. M. B., & Wardana, G. Pengunaan Model Problem Based Learning (PBL) dalam Meningkatkan Kemampuan Komunikasi Matematis Siswa. *FARABI Jurnal Matematika Dan Pendidikan Matematika*, *6*(1), 97–104, 2023. https://doi.org/10.47662/farabi.v6i1.581

[26] Suharno, Sulistiawati, & Arifin, S. Pengaruh Metode Thinking Aloud Pair Problem Solving (TAPPS) Terhadap Kemampuan Komunikasi Matematis Siswa SMP Negeri 1 Manggar. *Jurnal Numeracy*, *6*(1), 166–176, 2019. https://ejournal.bbg.ac.id/numeracy/article/view/1496

[27] Suhenda, L. L. A., & Munandar, D. R. Kemampuan Komunikasi Matematis Siswa Dalam Pembelajaran Matematika. *Jurnal Educatio*, *9*(2), 1100–1107, 2023. https://doi.org/10.31949/educatio.v9i2.5049

[28] Sumartini, T. S., & Safitri, L. Analisis Kesalahan Siswa SMP dalam Menyelesaikan Soal Cerita Sistem Persamaan Linear Dua Variabel Berdasarkan Prosedur Newman. *Prisma*, *11*(2), 302–309, 2022. https://doi.org/10.35194/jp.v11i2.2193

[29] Suryawati, Hasbi, M., Suri, M., & Kurniawati, S. Faktor yang Mempengaruhi Kemampuan Komunikasi Matematis Siswa SMP. *Journal of Education Science (JES)*, *9*(1), 7–16, 2023. https://doi.org/10.33143/jes.v9i1.2849

[30] Suswigi, & Zanthy, L. S. Kemampuan Pemahaman Matematik Siswa MTs di Cimahi Pada Materi Persamaan Garis Lurus. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, *3*(1), 40–46, 2019. https://doi.org/10.31004/cendekia.v3i1.77

[31] Trianto. *Model-model Pembelajaran Inovatif Berorientas Konstruktivistik*. Jakarta: Prestasi Pusaka, 2009.

[32] Yusri, A. Y. Pengaruh Model Pembelajaran Problem Based Learning Terhadap Kemampuan Pemecahan Masalah Matematika Siswa Kelas VII di SMP Negeri Pangkajene. *Jurnal Moshrafa*, *7*(1), 51–62, 2018. https://doi.org/10.31980/mosharafa.v7i1.474.