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Development of PBL-based teaching modules to improve the mathematical communication skills of phase D class VII students

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Abstract

This study aims to develop a product in the form of a mathematics teaching module based on the Problem-Based Learning (PBL) model to enhance students' mathematical communication skills in the context of linear equations and inequalities with one variable for Grade VII students in junior high schools (SMP/MTs). The study evaluates the teaching module's validity, practicality, and effectiveness. Additionally, the findings of this research can serve as a reference for teachers in designing teaching modules that improve communication skills in other mathematical topics and as a resource for students to practice and enhance their communication skills. This research is based on the importance of mathematical communication skills for students. According to the Ministry of National Education, one of the objectives of mathematics learning is to enable students to communicate their ideas through symbols, tables, diagrams, or other representations. However, field observations show that the reality is quite the opposite. The mathematical communication skills of Grade VII students (Phase D) in junior high schools are still relatively low, particularly in linear equations and inequalities with one variable. One of the indicators of this issue is that students do not create mathematical symbols accurately when solving problems. While they can solve problems presented in a format like the teacher's examples, they struggle with different problem formats, especially word problems, which are confusing. The data collection instruments used in this study include validation and practicality instruments. The data collection techniques involve interviews, questionnaires, and mathematical communication skill tests. The data analysis techniques employed are both quantitative and qualitative analyses. The development of the teaching module in this research follows the 4-D model (Four-D Model), which consists of four stages: defining, designing, developing, and disseminating.

Keywords: PLSV & PtLSV; mathematical communication skills; problem-based learning model.

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I. Introduction

Mathematics is a subject taught from elementary school to university levels. This subject is crucial as it serves as the foundation for learning various other disciplines (Ruqoyyah et al., 2020). Mathematics significantly contributes to multiple fields of science and the development of human thinking abilities. As a learning material, mathematics is essential to understand and functions as a conceptual tool for building and developing materials, training thinking skills, and supporting problem-solving in daily life (Kemdikbudristek, 2022).

According to Depdiknas, one objective of mathematics education is to enable students to communicate their ideas using symbols, tables, diagrams, or other media to clarify situations or problems (Oktoviani et al., 2019). Mathematical communication is related to constructing an understanding of mathematics learning materials by communicating mathematical thoughts using accurate mathematical language (Kemdikbudristek, 2022).

Hodiyanto (2017) stated that mathematical communication skills refer to students' abilities to convey mathematical ideas orally and in writing. These skills include the ability to express mathematical concepts, ideas, or situations in one's own words using mathematical representations such as diagrams, graphs, and tables and appropriately forming algebraic equations or mathematical models and symbols (Astuti & Sylviana Zanthy, 2019). Based on these learning objectives, all students must develop strong mathematical communication skills (Sopia & Kurniawati, 2021). By practicing communication in mathematics learning, students can foster and enhance their mathematical thinking skills, as communication activities in mathematics facilitate the development of mathematical reasoning (Hastuti et al., 2021) (Samo, 2017).

The above explanation concludes that mathematical communication is vital in mathematics learning. The ability to convey mathematical ideas verbally and in writing, using symbols, diagrams, and graphs, helps students understand mathematical concepts and strengthens their mathematical thinking. Communication activities in mathematics facilitate the development of mathematical reasoning, supporting learning objectives and enabling students to apply mathematics in real-life situations. Therefore, mastering mathematical communication is essential for students.

Despite its importance, students' mathematical communication skills often fall short in practice. Based on interviews conducted at Al-Ihsan Boarding School in Pekanbaru, it was found that student's ability to express events or ideas using mathematical symbols is still low. Students often answer problems directly without using mathematical symbols unless explicitly instructed. This observation aligns with studies by Wijayanto et al. (2018), Astuti & Zanthy (2019), and Sriwahyuni et al. (2019), which reveal that middle school students' mathematical communication skills are generally below average.

Nada, Darmawan, and Yohanes (2022) also reported that middle school students showed average mathematical communication skills based on test results. These findings highlight the need for serious attention to improving students' mathematical communication, particularly at the middle school level. Thus, solutions must be identified to enhance these skills.

The Role of Problem-Based Learning (PBL) in Enhancing Mathematical Communication improving students' understanding of learning materials is closely tied to the teaching strategies employed by educators during the learning process. Successful teaching requires selecting appropriate learning models. Active, discussion-based learning fosters students' communication skills (Baga et al., 2022). According to Sari (2014), the Problem-Based Learning (PBL) model enables students to explore mathematical objects, actively engage in mathematical processes, and restate mathematical ideas to form new understandings.

Students are trained to solve real-world problems by interpreting their ideas into mathematical symbols during this learning process. Research by Kurniati et al., (2019) indicates that the PBL model positively affects students' mathematical communication skills. Similarly, Duskri et al. (2017) found that implementing PBL improved students' mathematical communication abilities. The PBL model facilitates students in expressing diverse ideas when solving mathematical problems and fosters interaction, sharpening their communication (Kurniati et al., 2019).

PBL involves presenting a problem, posing questions, facilitating investigation, and encouraging student communication. The problems addressed should be contextual and relatable to students' daily lives (Rahyu & Fahmi, 2018). This model requires students to work independently and collaboratively to solve real-world problems (Nurjanah et al., 2022).

Developing Teaching Modules for Mathematical Communication Teaching modules are instructional tools designed based on the applicable curriculum to assist teachers in planning the learning process. Modules guide learning toward achieving desired outcomes (Armianto, 2022). Salsabilla, Jannah, and Juanda (2023) highlight that, in the Merdeka Curriculum, teachers play a crucial role in designing teaching modules. However, many teachers still struggle with this task.

Practical teaching modules start with real-world problems, making learning more relatable and engaging for students. Combining teaching modules with the PBL model can enhance students' mathematical communication skills. This research proposes developing PBL-based teaching modules for linear equations and inequalities with one variable, aimed at Grade VII middle school students.

Implementation and Expected Outcomes Research by Yusdia (2020) found that applying PBL to linear equations and inequalities increased students' mathematical communication skills by 82.06%. Similarly, Prasetiyo (2022) reported an 83% improvement in students' learning outcomes through PBL. Rahma and Kurniati (2024) also found significant improvements in students' understanding of mathematical concepts through PBL.

Despite its potential, many teachers fail to link this topic to real-life contexts, making it less engaging. Therefore, developing PBL-based teaching modules tailored to this topic can address this gap, making learning more meaningful and improving students' mathematical communication skills.

In conclusion, integrating PBL into teaching modules for linear equations and inequalities can significantly enhance students' mathematical communication skills. This approach aligns with the demands of the Merdeka Curriculum and provides a meaningful learning experience for students.

II. Research Method

This study adopts the 4-D development model, which consists of defining, designing, developing, and disseminating (Mulyatiningsih, 2014). The definition stage involves analyzing the curriculum, students, concepts, tasks, and goal specifications through interviews and documentation. Interviews are aimed at teachers to determine basic math problems, and documentation is carried out to determine learning achievements, concepts, and tasks for students.

The design stage in this study is a step for the researcher to determine the criteria and assessment tools for valid, practical, and effective teaching modules. The researcher also started to design the teaching module into prototype I.

The development stage is for researchers to get an assessment of the validity, practicality, and effectiveness of teaching modules. The teaching module is validated by expert assessment using a validation sheet. Students use a response questionnaire to carry out the teaching module. Moreover, the effectiveness of the teaching module is enhanced by a test of students' mathematical communication skills carried out at the beginning of the meeting and the end of the learning.

This research was conducted at SMPIT Al-Ihsan Boarding School with 32 grade VII students. The research instruments used in this study were validation sheets, student response questionnaires, and mathematical communication proficiency test questions.

III. Results and Discussion

The defined stage in this study aims to determine the problems that need to be solved. Through curriculum analysis, it is known that most teachers follow an independent curriculum but use learning platforms that do not support the active involvement of students. At the analysis stage, it was found that the students' mathematical communication skills were still relatively low, with the indicator being in showing mathematical expressions using symbols or mathematical models. This aligns with the findings (Azni & Jailani, 2015) that students have the lowest initiator to give mathematical ideas with symbols or mathematical models because it is difficult to determine the correct symbols. These results require teachers to find ways to develop students' mathematical communication skills. In the concept analysis stage through the analysis of learning outcomes, it is known that the material of one-variable linear equations and inequalities consists of five sub-materials, namely, closed and open sentences, one-variable linear equations, one-variable linear equation solution graphs, one-variable linear inequalities, and one-variable linear inequalities graphs. In this concept, students are required to be able to distinguish between open and closed sentences, solve contextual problems related to PLSV and PtLSV, and describe graphs to solve PLSV and PtLSV problems.

The design stage, which aims to produce an initial design of the teaching module, begins with the results of making validation sheets, student response questionnaires, and mathematical communication proficiency test questions. The following is the initial draft of the resulting teaching module.

a) Teaching module cover.

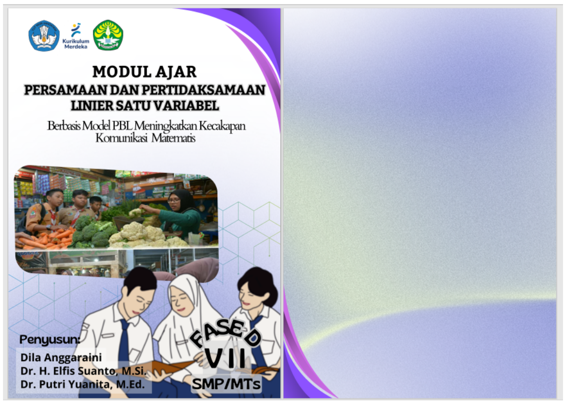

Figure 1. Cover of teaching module

b) Fill in the teaching module

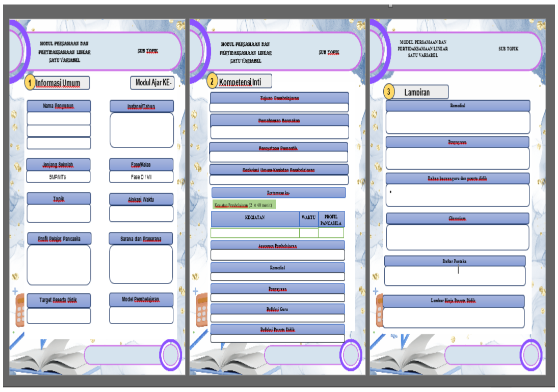

Figure 2. Contents of the teaching module

The design of the teaching module that the researcher has found is then discussed with the supervisor, and a validity, practicality, and feasibility test
is continued.

Three mathematics lecturers carried out the validity test, guided by the validation sheet, and obtained the following results.

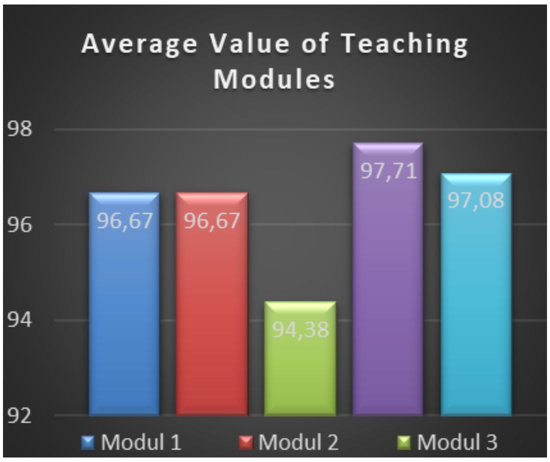

Figure 3. Teaching module validation results

Figure 3 shows that the five teaching modules in this study have met the very valid category with a score criterion of ≥ 90%.

The practicality test was carried out by field trials on the usability of teaching modules to 32 students. The results of the student response questionnaire are presented in Figure 4.

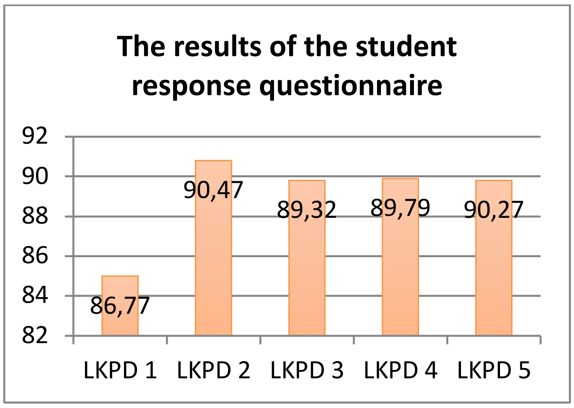

Figure 4. The results of the student response questionnaire

Figure 4 shows that the students feel the practicality of the teaching model, so the score obtained from each LKPD used is ≥85%, which concludes that the LKPD in the attachment of the teaching module is very practical. The results of the teacher's responses to the field trial can be seen in Figure 5 as follows.

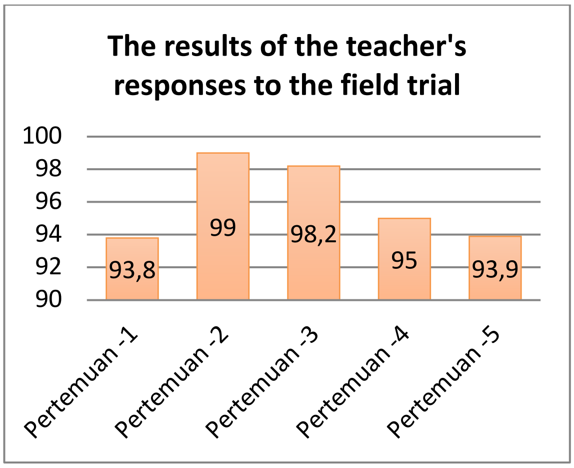

Figure 5. The results of the student response questionnaire

Figure 5 shows that the practicality of the teaching module is felt by the teacher, concluding that the teaching module has very practical criteria with a percentage above 90%.

An effectiveness test is needed to determine the influence of teaching modules on improving students' mathematical communication skills. The test results before and after the implementation of learning with the teaching module developed by the researcher were used to determine the improvement of mathematical communication skills. The improvement of mathematical communication skills was carried out by testing the similarity of two averages on the results of the students' pretest and posttest.

1) Analysis of Initial Test Data (pretest)

The results of the pretest analysis are descriptive, as shown in Table 1 of the experimental class and sample class as follows:

Table 1. Descriptive analysis of pretest data

No.	Statistics Measures	*Pretest*	
		Experiment Class	**Control Class**
1.	Mean	13.53	14.56
2.	Minimum Score	4	3
3.	Maximum Score	22	25
4.	Range	18	22
5.	Variant	19.483	35.483
6.	Deviation St.	4.412	5.951

Source: Researcher Data Processing, 2024

Based on the data obtained, the average pretest score in the experimental class was 13.53, while in the control class, it was higher, at 14.56. The minimum score recorded in the experimental class is 4, while the control class has a minimum score of 3. On the other hand, the maximum score in the experimental class is 22, while in the control class, it reaches 25. The range or difference between the maximum and minimum scores in the experimental class was 18, while the control class was more significant, namely 22. The variance in the experimental class was 19,483, lower than the control class, which had a variance of 35,483, indicating that the control class scores are more dispersed. Likewise, with the standard deviation, the experimental class has a standard deviation 4,412. In contrast, the control class has a higher standard deviation, which is 5,951, indicating a more significant variation in the distribution of scores in the control class. This analysis provides an overview of the differences in distribution and variation of scores between the two classes in the pretest.

2. Results of the Pretest Data Normality Test

The data normality test uses the Kolomogorov-Smirnov test. The results of the sample class pretest normality test are in the following Table 2:

Table 2 Results of pretest normality test

Class	Kolmogorov-Smirnov[a]		
	Statistic	Df	Sig.
Experiment	0.146	32	0.083
Control	0.150	32	0.066

Source: Research Data Processing, 2024

Table 2 shows that the value (sign.) of the experimental and control classes is more than α = 0.05, so "H_0" is accepted, meaning that the score data of both sample classes is normally distributed.

3. Results of Pretest Data Homogeneity Test

The homogeneity test uses Bartlett Box's M test. The results of the homogeneity test of the pretest score data are shown in Table 3 below:

Table 3. Pretest data homogeneity test

Test Results	
Box's M	2.728
Sig.	0.101

Source: Research Data Processing, 2024

The calculation results in Table 3 show that if the sig value is > 0.05, then "H_1" is rejected, meaning that the sample class's pretest score data is homogeneous.

4. Results of the Similarity Test of Two Average Pretest Score Data

The results of the similarity test of the two average pretest scores are in Table 4.

Table 4. Test two average sample class pretest

Class	N	Mean	Deviation St.	Sig. 2-Tailed	t
Experiment	32	13.53	4.414	0.434	-.787
Control	32	14.56	5.951		

Source: Research Data Processing, 2024

Based on Table 4, the pretest data of experimental students and control classes were obtained significance (sign.) = 0.434 > ∝ = 0.05, so that "H_0" was accepted and "H_1" was rejected. This means there is no difference in the average KKM pretest between the two sample classes.

5. Final Test Data Analysis (posttest)

The results of the descriptive posttest data analysis can be seen in the following Table 5:

Table 5. Results of descriptive posttest data analysis of sample class

No.	Statistics Measures	***Posttest***	
		Experiment Class	Control Class
1.	Mean	35.22	30.53
2.	Minimum Score	16	22
3.	Maximum Score	43	36
4.	Range	27	14
5.	Variant	39.144	12.257
6.	Deviation St.	6.257	3.501

Source: Research Data Processing, 2024

In the analysis of the posttest data of the two classes, which can be seen in Table 4.15, several statistical measures describe the posttest results for the experimental and control classes. Descriptively, the analysis results showed that the average posttest score in the experimental class was 35.22, higher than the control class, which had an average of 30.53. The minimum score for the experimental class is 16, while the control class has a minimum score of 22. The maximum score in the experimental class reached 43, while the control class reached 36. The range or difference between the maximum and minimum scores in the experimental class was 27, while in the control class, it was smaller, which was 14. The variance in the experimental class (39,144) was much higher than in the control class (12,257), which indicates a more significant variation in the experimental class. The standard deviation in the experimental class was also larger, at 6,257, compared to the control class, which had a standard deviation of 3,501. Thus, the results of this descriptive analysis show differences in the distribution and variation of scores between the two classes.

6. Posttest Data Normality Test

The results of the normality test of the sample class posttest data are shown in Table 6 below:

Table 6. Results of the normality test of posttest score data for sample classes

Class	Kolmogorov-Smirnov[a]		
	Statistic	Df	Sig.
Experiment	0.133	32	0.157
Control	0.135	32	0.148

Source: Research Data Processing, 2024

Table 6 presents the results of the normality test of posttest score data for the sample class using the Kolmogorov-Smirnov test. In the experimental class, the statistical value of Kolmogorov-Smirnov was 0.133 with a significance value (Sig.) of 0.157, while in the control class, the statistical value of Kolmogorov-Smirnov was 0.135 with a significance value (Sig.) of 0.148. Since the significance value in both classes is more significant than 0.05, the null hypothesis (H_0) states that the data are typically distributed. Thus, it can be concluded that the posttest score data for the experimental class and the control class are normally distributed.

7. Posttest Data Homogeneity Test

Hypothesis Test Two Average Posttest Scores of Sample Class

The results of the posttest homogeneity test are shown in Table 7 below:

Table 7. Sample class posttest homogeneity test

Test Results	
Box's M	9.910
Sig.	0.002

Source: Research Data Processing, 2024

Table 7 shows the data sig < 0.05, so H_0 is rejected. This means that the posttest data does not have a homogeneous variation or a variance difference between the experimental and control classes being tested.

8. Posttest Average Value

Table 8. Posttest average value

Class	N	Mean	Deviation St.	Sig. (2-Tailed)	T
Experiment	32	35.22	6.257	0.001	3.699
Control	32	30.53	3.501		

Source: Research Data Processing, 2024

The hypothesis test results of the two average posttest scores of the sample class presented in Table 8 show a significant difference between the experimental and control classes. In the experimental class, the average posttest score was 35.22, with a standard deviation of 6,257, while in the control class, the average posttest score was 30.53, with a standard deviation of 3,501. The significance value (Sig. 2-tailed) obtained from the statistical test was 0.001, below the significance level of 0.05. This shows that the null hypothesis (H_0) is rejected, so it can be concluded that there is a significant difference between the experimental and control classes' posttest scores. These results indicate that the learning method applied to the experimental class has a more significant influence on the achievement of learning outcomes than the learning method applied to the control class.

9. Data Analysis of KKM Increase (N-gain)

Table 9. Results of the similarity test of two averages

	Pretest		*Postest*	
Class	Mean	Sig. (2-Tailed)	Rata-Rata	Sig. (2-Tailed)
Experiment	13.53	0.434	35.22	0.001
Control	14.56		30.53	

Source: Research Data Processing, 2024

Table 9 shows that the pretest in the experimental and control classes has a significance value of 2. tailed 0.434, which is the significance (sign.) > 0.05 and means that at the beginning of learning, the two classes have an average similarity regarding their mathematical communication skills. However, after the use of teaching modules in the experimental class and the control class with learning as usual, it was found that the posttest in the experimental class and the control class had a significance value of 2. tailed 0.001, namely significance (sign.) < 0.05 which means that there was a difference in the mathematical communication skills of students from the two classes. In this case, an n-gain test was carried out to determine how effective the learning was in the two classes with different treatments. The results of the n-gain test are in Table 10.

Table 10. The results of the n-gain test

No.	Statistics Measures	Gain	
		Experiment Class	Control Class
1.	Mean	0.6175	0.2638
2.	Minimum Score	16	10
3.	Maximum Score	85	70

Source: Research Data Processing, 2024

Table 10 shows that the average with the n-gain test is 0.6175 in the experimental class and 0.2638 in the control class. The average obtained in the experimental class means that the teaching module's effectiveness is in the medium category, and the effectiveness of the control class is in the low category. So, it is concluded that the teaching module developed in this study has effective criteria for improving students' mathematical communication skills on the topic of one-variable linear equations and inequalities.

The dissemination stage in this study involved the teaching module that was tested, which was practically and effectively disseminated to schools that contributed to this research and were seminars in public spaces.

IV. Conclusion

The development research produced a product as a teaching module on linear equations and inequalities in one variable based on problem-based learning, designed to improve the mathematical communication skills of phase D students. The research procedure was carried out using a 4-D model (four D Model), namely the definition stage (define), planning stage (design), development stage (development), and dissemination stage (disseminate). The conclusion obtained from the development stage process can be concluded that the development of teaching modules on the topic of single-variable linear equations and inequalities based on problem-based learning produces teaching modules that are valid, practical, and effective in improving the mathematical communication skills of Phase D students.

The results of this study indicate that the teaching method applied in the experimental class had a more significant influence on learning outcomes than the method used in the control class. The findings are as follows: In the experimental class, the average posttest score was 35.22 with a standard deviation of 6.257, while the average posttest score in the control class was 30.53 with a standard deviation of 3.501. The significance value (Sig. 2-tailed) obtained from the statistical test was 0.001, below the 0.05 significance level. This indicates that the null hypothesis (H_0) is rejected, concluding that there is a significant difference between the posttest scores of the experimental and control classes.

The N-Gain analysis shows that the experimental class experienced a more significant improvement in learning outcomes than the control class due to a significant increase in mathematical communication skills (MCS) between the two groups. The average MCS improvement in the experimental class was 0.6175, substantially higher than the 0.2638 recorded in the control class. Thus, the teaching method implemented in the experimental class was proven to be more effective in enhancing students' MCS than the control class, highlighting the positive impact of the teaching module on learning.

Student responses to the teaching module were also highly positive, with the practicality percentage in the field trials exceeding 80%. Additionally, teachers' assessments of the teaching module yielded scores above 90% for each session, confirming that the module is highly practical and relevant for classroom use.

Overall, the development of this PBL-based teaching module successfully addressed the research problem and provided solutions for mathematics learning, particularly on the topic of linear equations and Inequalities in One Variable.

Therefore, the developed teaching module can be valid, practical, and effective for supporting problem-based learning in Grade VII of SMP/MTs.

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