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The Effect of Implementing the Problem-Based Learning Model on the Systematic Communication Skills of Grade XI Students at SMAN 2 Padang

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Abstract- This study was motivated by the low level of students' mathematical communication skills in mathematics learning. One learning model that can encourage students to participate actively in the problem-solving process is Problem Based Learning (PBL). This study aimed to determine and describe the mathematical communication skills of students taught using the PBL model compared to those taught using direct instruction in Grade XI, Phase F, at SMA Negeri 2 Padang. This research employed a quasi-experimental method with a The Nonequivalent Posttest-Only Control Group Design. The research sample consisted of 66 students, comprising 29 students in the experimental class taught using the PBL model and 37 students in the control class taught using direct instruction. Data on students' mathematical communication skills were collected through a posttest consisting of essay questions developed based on three indicators of mathematical communication skills. The data were analyzed using descriptive statistics and the Mann-Whitney U test. The results showed that the mean score of the experimental class was 80.90, while the control class obtained a mean score of 77.59. However, the Mann-Whitney U test yielded an Asymp. Sig. (2-tailed) value of 0.658, which was greater than the significance level of 0.05. Therefore, there was insufficient statistical evidence to conclude that the mathematical communication skills of students taught using the PBL model were better than those of students taught using direct instruction.

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1. Introduction

Mathematics learning involves more than understanding concepts and applying formulas. Students are also expected to communicate mathematical ideas, explain their reasoning, and present solutions to problems in a clear and systematic manner. Mathematical communication skills are therefore an important aspect of mathematics learning because they enable students to express their understanding through mathematical language, symbols, diagrams, and written explanations (Anderha, 2020; Istiqomah, 2022). These skills also help students convey their ideas and understand mathematical concepts more effectively (Ashim, 2019; Chalim, 2019).

However, students' mathematical communication skills remain a challenge in the learning process. Based on observations of mathematics learning at SMA Negeri 2 Padang, students tended to receive explanations delivered by the teacher and were less actively involved in expressing their mathematical ideas. When the teacher provided opportunities to ask questions, most students remained silent and did not ask questions about the material. Students were then asked to solve problems in groups and present the results of their discussions. This learning situation indicates that students need more opportunities to actively express, explain, and develop their mathematical ideas. In particular, students need to be encouraged to communicate mathematical information in written form, explain mathematical ideas through diagrams, and translate problems in everyday contexts into mathematical models (Kurniawan, 2017).

One learning model that can provide opportunities for students to participate actively in solving mathematical problems is Problem Based Learning (PBL). PBL places problems as the starting point of the learning process and encourages students to investigate and develop solutions individually or collaboratively (Khofshoh et al, 2020). Through this learning model, students are involved in identifying problems, discussing possible solutions, conducting investigations, and presenting the results of their work. These activities provide opportunities for students to express their ideas, explain their reasoning, and communicate mathematical solutions. Sunardi, Nuranti & Hasratuddin (2023) and Nurbaiti et al (2016), as cited in Wijaya and Yusup (2023), explain that PBL encourages students to participate actively in solving mathematical problems, both individually and in groups. Therefore, PBL is considered a relevant alternative for providing learning experiences that involve students in communicating mathematical ideas.

Several previous studies have examined the relationship between PBL and students' mathematical communication skills. Zahrotin et al. (2020) found that the implementation of PBL improved the mathematical communication skills of third-grade students at MI Muhammadiyah Kramat. The improvement was particularly evident in students' ability to explain mathematical ideas, situations, and relationships through real objects, pictures, graphs, and algebraic representations. Similarly, Humaira and Miatun (2023) reported that students who learned through PBL demonstrated better mathematical communication skills than those who did not receive PBL instruction. Their study also indicated that students' anxiety levels were related to their mathematical communication skills. Furthermore, Daulay et al. (2020) found that the improvement in mathematical communication skills among students taught using PBL was better than that of students taught using the Think Pair Share (TPS) model. Kodariyati and Astuti (2016) also reported a positive and significant effect of PBL on the mathematical communication and problem-solving skills of elementary school students.

Although previous studies have reported positive findings regarding the use of PBL, they were conducted at different educational levels and in different learning contexts. Therefore, further research is needed to examine the implementation of PBL among senior high school students, particularly by comparing their mathematical communication skills with those of students receiving direct instruction. This study focuses on Grade XI students in Phase F at SMA Negeri 2 Padang. It examines three indicators of mathematical communication skills: understanding mathematical ideas in written problem-solving,

explaining mathematical ideas through diagrams, and translating everyday problems into mathematical models.

Based on this background, this study aims to determine and describe the mathematical communication skills of students taught using Problem Based Learning compared with those taught using direct instruction in Grade XI, Phase F, at SMA Negeri 2 Padang. The findings are expected to provide empirical information about the comparison of students' mathematical communication skills under these two learning approaches.

2. Methods

This study employed a quantitative method with a quasi-experimental design to compare the mathematical communication skills of students taught using the Problem Based Learning (PBL) model and those taught using direct instruction. The research used The Nonequivalent Posttest-Only Control Group Design. The participants consisted of 66 Grade XI students at SMA Negeri 2 Padang, with 29 students in the experimental group and 37 students in the control group. Data were collected through a written mathematical communication test administered at the end of the learning process. The data were analyzed using descriptive statistics and the Mann-Whitney U test to examine the differences in students' mathematical communication skills between the two groups.

(a) Data and Variables

The data used in this study are primary data obtained directly from students' posttest results at SMA Negeri 2 Padang during the 2024/2025 academic year. The study involved 66 Grade XI students, consisting of 29 students in the experimental group taught using the Problem Based Learning (PBL) model and 37 students in the control group taught using direct instruction. The data were collected through a written test consisting of four essay questions designed to measure students' mathematical communication skills based on three indicators. The analysis focused on comparing students' mathematical communication skills between the two groups.

Variable Name	Variable Type	Description
Learning Model	Independent Variable (X)	The learning model applied in the classroom, consisting of Problem Based Learning (PBL) in the experimental group and direct instruction in the control group.
Mathematical Communication Skill	Dependent Variable (Y)	Students' mathematical communication skills measured through their posttest scores on a written test consisting of four essay questions.

(b) Steps of Analysis

Rstudio software was used to analyze the data. The steps in this study were as follows:

1. Descriptive Data
   Descriptive statistical analysis was conducted to describe students' mathematical communication skills in the experimental and control groups. The analysis included the number of students, mean score, standard deviation, highest score, and lowest score obtained from the posttest results.

2. Assumption Testing
   Before conducting the hypothesis test, normality and homogeneity tests were performed to examine the distribution of the data and the equality of variances between the two groups.

   The normality test was conducted using the Shapiro-Wilk test because the number of students in each group was fewer than 50. The test was used to determine whether the posttest scores in each group followed a normal distribution. The hypotheses for the normality test were:

H_0: The data are normally distributed.
H_1: The data are not normally distributed.

The decision was based on the significance value. If the significance value was greater than 0.05, H_0 was not rejected, indicating that the data were normally distributed. Conversely, if the significance value was less than or equal to 0.05, H_0 was rejected, indicating that the data were not normally distributed.

The homogeneity test was conducted using Levene's test to determine whether the variances of the experimental and control groups were equal. The hypotheses were:

H_0: The variances of the two groups are equal.
H_1: The variances of the two groups are not equal.

If the significance value was greater than 0.05, the variances were considered homogeneous. If the significance value was less than or equal to 0.05, the variances were considered non-homogeneous.

3. Hypothesis Testing
The hypothesis was tested using the Mann-Whitney U test because the normality test results indicated that the posttest data in both groups were not normally distributed. This non-parametric test was used to examine whether there was a statistically significant differencModeling using Poisson Regressione in students' mathematical communication skills between the experimental group taught using the Problem Based Learning (PBL) model and the control group taught using direct instruction.
The hypotheses of the Mann-Whitney U test were:

H_0: There is no statistically significant difference in mathematical communication skills between students taught using the PBL model and those taught using direct instruction.
H_1: There is a statistically significant difference in mathematical communication skills between the two groups.

The decision was based on the Asymp. Sig. (2-tailed) value. If the significance value was less than 0.05, H_0 was rejected. Conversely, if the significance value was greater than or equal to 0.05, H_0 was not rejected.

4. Hypothesis Testing Using The Mann-Whitney U-Test
The Mann-Whitney U test is a nonparametric statistical test used to determine whether there is a statistically significant difference between two independent groups. This test is an alternative to the independent samples t-test when the data do not meet the normality assumption. In this study, the Mann-Whitney U test was used to compare the mathematical communication skills of students taught using the Problem Based Learning (PBL) model and those taught using direct instruction.

The test was conducted by comparing the ranking of students' posttest scores in the two groups. The hypotheses were formulated as follows: the null hypothesis (H_0) states that there is no statistically significant difference in mathematical communication skills between students taught using the PBL model and those taught using direct instruction. Meanwhile, the alternative hypothesis (H_1) states that there is a statistically significant difference between the two groups.

The decision was based on the Asymp. Sig. (2-tailed) value at a significance level of 0.05. If the significance value is less than 0.05, H_0 is rejected. Conversely, if the significance value is greater than or equal to 0.05, H_0 is not rejected.

3. Results and Discussion

(a) Data and Variables

Descriptive statistics of the data are presented in Table 1.

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Table 1. Descriptive statistics of the data

Group	N	Minimum	Maximum	Mean	Standard Deviation
Eksperimental (PBL)	29	0	100	80.90	29.513
Control (Direct Instruction)	37	19	100	77.59	29.453
Total	66	-	-	-	-

Based on the descriptive statistical analysis, the experimental group taught using the Problem Based Learning (PBL) model consisted of 29 students, with an average posttest score of 80.90 and a standard deviation of 29.513. Meanwhile, the control group taught using direct instruction consisted of 37 students, with an average posttest score of 77.59 and a standard deviation of 29.453. The minimum score in the experimental group was 0, while the control group obtained a minimum score of 19. Both groups achieved a maximum score of 100. Descriptively, the experimental group obtained a higher mean score than the control group. However, further statistical testing is required to determine whether the difference between the two groups is statistically significant.

(b) Assumption Test

The assumption tests in this study consisted of normality and homogeneity tests. The normality test was conducted using the Shapiro-Wilk test to determine whether the posttest scores in each group were normally distributed. The results showed that the significance value for the experimental group was 0.000, while the control group also obtained a significance value of 0.000. Since both values were less than 0.05, the posttest scores in both groups were not normally distributed.

Furthermore, the homogeneity test was conducted using Levene's test to determine whether the variances of the two groups were equal. The test produced a significance value of 0.595, which was greater than 0.05. Therefore, the variances of the experimental and control groups could be considered homogeneous.

The normality test was conducted using the Shapiro-Wilk test to determine whether the posttest scores in each group were normally distributed. The results are presented in Table 2.

Table 2. Result of Normality Test

Group	Shaphiro-Wilk Statistic	df	Sig.
Experimental	0.694	29	0.000
Control	0.743	37	0.000

Based on Table 2, the experimental group obtained a significance value of less than 0.001, and the control group also obtained a significance value of less than 0.001. Both values were below the significance level of 0.05. Therefore, the posttest scores in both groups were not normally distributed. These results indicate that the normality assumption was not met.

The homogeneity test was conducted using Levene's test to determine whether the variances of the experimental and control groups were equal. The results are presented in Table 3.

Table 3. Result of Homogenity Test

Test	Levene Statistic	Sig.
Equality of Variances	0.694	0.595

Based on Table 3, the Levene's test produced a significance value of 0.595, which was greater than the significance level of 0.05. Therefore, the null hypothesis of equal variances was not rejected, indicating that the posttest scores of the experimental and control groups had homogeneous variances. Although the homogeneity assumption was met, the normality assumption was not satisfied. Therefore, the Mann-

Whitney U test was used for hypothesis testing.

(c) Hypothesis Testing Using the Mann-Whitney U Test

The hypothesis testing was conducted using the Mann-Whitney U test to determine whether there was a statistically significant difference in mathematical communication skills between students taught using the Problem Based Learning (PBL) model and those taught using direct instruction. The test results are presented in Table 4.

Table 4. Results of the Mann-Whitney U Test

Statistic	Value
Mann-Whitney U	504.500
Wicolxon W	1207.500
Z	-0.443
Asymp. Sig. (2-tailed)	0.658

Based on Table 4, the Mann-Whitney U test produced an Asymp. Sig. (2-tailed) value of 0.658, which was greater than the significance level of 0.05. Therefore, the null hypothesis (H_0) was not rejected. This indicates that there was no statistically significant difference in mathematical communication skills between students taught using the Problem Based Learning (PBL) model and those taught using direct instruction.

Although the experimental group obtained a higher average posttest score of 80.90 compared to 77.59 in the control group, this difference was not statistically significant. Thus, the results do not provide sufficient statistical evidence to conclude that students taught using the PBL model had better mathematical communication skills than those taught using direct instruction.

(d) Discussion

The results showed that students in the experimental group taught using the Problem Based Learning (PBL) model obtained a higher mean score (80.90) than students in the control group taught using conventional learning (77.59). However, the Mann-Whitney U test showed an Asymp. Sig. (2-tailed) value of 0.658, which was greater than the significance level of 0.05. This indicates that there was no statistically significant difference in students' mathematical communication skills between the two groups. Although the experimental group achieved a higher average score, the difference was not sufficient to demonstrate a significant difference between the learning models.

Several previous studies have examined the implementation of PBL in developing students' mathematical communication skills, including Zahrotin et al. (2020), Humaira and Miatun (2023), Daulay et al. (2020), and Kodariyati and Astuti (2016). In general, these studies provide a relevant basis for examining the relationship between problem-based learning and mathematical communication skills. PBL involves learning activities that encourage students to understand problems, discuss possible solutions, express mathematical ideas, and present their findings. These activities are closely related to mathematical communication skills, particularly in explaining mathematical ideas, using diagrams, and translating everyday problems into mathematical models. Nevertheless, the findings of the present study indicate that the implementation of PBL did not produce a statistically significant difference compared with conventional learning.

The difference in mean scores between the two groups may be related to the learning experiences and levels of student participation during the learning process. Through PBL, students have opportunities to engage in problem-solving activities and communicate their ideas with others (Wijayanto et al, 2018). However, students may require sufficient time and practice to develop the ability to express mathematical ideas systematically in written form. Differences in students' readiness and participation may also influence their learning outcomes. Therefore, although PBL provides learning activities that

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support mathematical communication, its implementation in this study did not result in a statistically significant difference (Wahyuningsih, 2019; Zaditania & Ruli, 2022). Further research with a longer implementation period and different learning contexts is needed to examine this finding.

4. Conclusion

Based on the results of this study, students taught using the Problem Based Learning (PBL) model obtained a higher mean score in mathematical communication skills (80.90) than students taught using conventional learning (77.59). However, the Mann-Whitney U test showed a significance value of 0.658, which was greater than 0.05. This indicates that there was no statistically significant difference in mathematical communication skills between the two groups. Therefore, this study does not provide sufficient statistical evidence to conclude that PBL is better than conventional learning in improving students' mathematical communication skills. Further research is recommended to examine the implementation of PBL with a longer learning period and in different educational contexts.

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