

The effect of problem based learning model with scientific approach on the mathematical communication skills

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Abstract

Mathematical communication is a crucial competency for students in mathematics education; nevertheless, learners frequently struggle to articulate and convey mathematical concepts. This research examined the impact of integrating the Problem-Based Learning (PBL) model with a scientific approach on the mathematical communication abilities of secondary school students. Utilizing a quantitative design with a quasi-experimental approach, specifically a posttest-only control group design, the study selected participants via cluster random sampling, involving 56 students from two classes at SMA Negeri 1 Purwonegoro during the 2025/2026 academic year. Class X-8, consisting of 30 students, was assigned as the experimental class and received the PBL model integrated with a scientific approach, while Class X-6, consisting of 26 students, served as the control class and received conventional learning. Data collection relied on mathematical communication assessments and instructional observations. Subsequent analysis using normality, homogeneity, and independent samples t-tests in SPSS yielded a significance score of 0.017 ($p < 0.05$), thereby rejecting the null hypothesis (H_0) and accepting the alternative hypothesis (H_1). The results confirm that incorporating a scientific approach into PBL substantially enhances students' mathematical communication skills. Furthermore, the instructional implementation attained an average score of 88%, placing it in the "very good" category.

Keywords: Mathematical Communication Skills; Problem-Based Learning; Scientific Approach; Senior High School Students

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INTRODUCTION

Communication plays a foundational role in the study of mathematics, as learners must articulate mathematical concepts clearly to ensure peer and instructor comprehension. This ability involves explaining the reasoning used to solve problems, interpreting mathematical representations, and presenting the results of mathematical thinking both orally and in written form. Siregar (2018) states that mathematical communication contributes to students' understanding by enabling them to organize and express their mathematical thoughts. It is also closely related to activities such as identifying patterns, solving problems, and formulating conclusions, while providing a means to communicate their ideas in systematic and understandable way (Hodiyanto, 2017; Marniati et al., 2021)

Nevertheless, students' mathematical abilities in Indonesia still need attention. According to PISA 2022, Indonesia obtained a mean mathematics score of 366 points, below the OECD average of 472 points, and only 18% of Indonesian students reached at least Level 2 proficiency, compared with 69% across OECD countries (OECD, 2023). PISA primarily measures mathematical literacy, which is conceptually related to mathematical communication because solving contextual problems requires students to understand information, use mathematical representations and symbols, and communicate their reasoning. However, PISA does not directly measure mathematical communication skills. Wijaya & Yusup (2023) found that students' written mathematical communication skills were predominantly moderate, with 9 of 12 students classified in this category, indicating the need for learning activities that encourage students to express, represent, and communicate mathematical ideas.

Low mathematical communication skills are still a problem experienced by some students. This is in line with the findings Ahmad & Nasution (2018) which shows that students still face obstacles in translating contextual problems into mathematical models, converting image representations into mathematical symbols, and conveying information using mathematical language appropriately. In addition, Marniati et al (2021) Explains that mathematical communication skills include several aspects, namely the ability to turn real situations into mathematical ideas, represent mathematical ideas through pictures or graphs, and translate everyday problems into mathematical language and symbols to obtain appropriate solutions.

This problem was also identified by Preliminary observations of classroom learning indicated that students still experienced difficulties in expressing, representing, and communicating mathematical ideas. Students tended to have difficulty explaining their reasoning and translating problems into appropriate mathematical representations. at SMA Negeri 1 Purwonegoro, Banjarnegara, Central Java. An initial assessment of students' mathematical communication skills was conducted involving 30 students using a written mathematical communication test. The test assessed three indicators of mathematical communication: (1) expressing situations, real objects, and pictures into mathematical ideas using their own words; (2) expressing and representing mathematical ideas in the form of pictures, real objects, or graphs; and (3) expressing everyday events using mathematical language or symbols to solve mathematical problems. The

assessment yielded an average score of 59.17, with individual scores ranging from 30 to 90. Based on the predetermined assessment criteria, the average score of 59.17 was categorized as low, indicating that students' mathematical communication skills still needed to be improved. This condition highlights the need for an instructional model that can actively involve students in understanding, expressing, representing, and constructing mathematical ideas during the learning process.

Problem-Based Learning (PBL) is a student-centered instructional model that uses contextual problems as the basis of learning. Its main stages include orienting students to the problem, organizing students for learning, guiding investigation, developing and presenting solutions, and evaluating the problem-solving process. These learning activities create opportunities for students to construct their understanding while strengthening their mathematical thinking and communication skills (Hmelo-Silver, 2004; Meilasari et al., 2020). Placing real-world issues at the core of education enables learners to think critically, share perspectives, work together, gather necessary information, and create practical solutions. Through these learning activities, students gain a wider range of opportunities to develop and communicate their mathematical ideas. Research by Ghaida & Fatimah (2024) students' abilities in mathematical communication showed improvement following the application of Problem-Based Learning. Similar evidence was reported in a study by Suprojo et al. (2025) A similar improvement in students' ability to communicate mathematical ideas was reported after the PBL model was implemented. Furthermore, Saefuloh et al. (2023) highlighted that PBL plays a crucial role in fostering students' mathematical thinking and problem-solving abilities, which are essential components for constructing effective mathematical communication.

The scientific approach is a learning approach that actively involves students in constructing knowledge through systematic scientific activities. It is characterized by the stages of observing, questioning, collecting information, associating, and communicating (Darmayanti, 2019; Musfiqon & Nurdyansyah, 2015). This approach encourages students to investigate problems, process information, develop logical reasoning, and communicate their findings. Its advantages include promoting active student participation, critical and creative thinking, independent learning, and the ability to communicate ideas systematically. However, its implementation may require sufficient

time, careful teacher guidance, and active student participation. Therefore, integrating the scientific approach into PBL can provide opportunities for students to investigate problems, develop mathematical reasoning, and communicate mathematical ideas more systematically (Wati & Loviana, 2022).

Previous research has provided evidence of the positive contribution of integrating PBL with a scientific approach to mathematics learning. Research Hasriyani et al (2022) reveals that students experienced a notable increase in their mathematical problem-solving proficiency after the model was introduced. Panggabean et al. (2025) also reported a positive effect of implementing PBL with a scientific approach on students' mathematics learning outcomes. In addition, the research Mayasari et al (2022) The study found that implementing PBL encouraged increased student engagement throughout the learning process.

However, previous studies still focus on supporting the development of students' problem-solving abilities, academic achievement, and student activity. Meanwhile, research that specifically examines the effect of the implementation of the PBL model combined a scientific approach on the mathematical communication skills is still relatively limited. Based on these problems, this study aimed to provide empirical evidence on how integrating the PBL model with a scientific approach influences students' mathematical communication skills. Grounded in the recognized importance of these communication abilities, the research was carried out and this study aims to provide empirical evidence and determine the effect of the Problem-Based Learning model integrated with a scientific approach on students' mathematical communication skills.

METHODS

This research utilized a quantitative methodology adopting a quasi-experimental design, specifically a posttest-only control group design. Conducted at SMA Negeri 1 Purwonegoro during the second semester of the 2025/2026 academic year, the study encompassed a total population of 310 tenth-grade students. The samples were selected using cluster random sampling, in which classes were randomly selected as intact groups from the population (Asrulla et al., 2023). Based on the randomization process, class X-8 was assigned as the experimental cohort, while class X-6 served as the control cohort. The experimental cohort learned via a scientific-approach-integrated PBL model, while the control cohort followed conventional teaching methods. The study focused on two

sample groups (experimental and control), the layout of which is presented in Table 1 (Soesana et al., 2023).

Table 1. Posttest-Only Control Group Design

Group	Treatment	Posttest
R	X	O1
R	-	O2

Note. X = Implementation of Problem-Based Learning model with a scientific approach; O1 = Observation or measurement of the dependent variable in the experimental class; O2 = Observation or measurement of the dependent variable in the control class; R = Random data collection (Randomization).

The study was conducted on the topic of statistics for tenth-grade students over four learning meetings. The independent variable (X) was the Problem-Based Learning model integrated with a scientific approach, while students' mathematical communication skills were the dependent variable (Y). In the experimental class, learning followed the PBL stages of orienting students to problems, organizing group learning, guiding investigation, presenting solutions, and evaluating the problem-solving process, integrated with the scientific approach of observing, questioning, collecting information, associating, and communicating. Research data were obtained through the implementation of tests and observation activities.

The instrument consisted of a written posttest and an observation sheet. The posttest consisted of five essay questions designed to assess students' mathematical communication skills based on three indicators: (1) expressing situations, real objects, and pictures into mathematical ideas using their own words; (2) representing mathematical ideas through pictures, real objects, or graphs; and (3) expressing everyday situations using mathematical language or symbols to solve mathematical problems. Each response was scored using an indicator-based rubric according to the accuracy and completeness of students' mathematical communication. The observation sheet was used to assess the implementation of PBL integrated with a scientific approach during the learning process. The implementation was categorized based on the percentage of observed activities into predetermined criteria.

The data was analyzed using SPSS software. Before testing the hypothesis, normality and homogeneity tests were performed on the collected data. Furthermore, the

research hypothesis concerning the effect of the scientific-approach-integrated PBL model on students' mathematical communication abilities was examined using an independent samples t-test with a significance level set at 0.05.

RESULTS AND DISCUSSION

Descriptive Statistics of Posttest Results

A posttest-only control group design was utilized in this investigation to evaluate students' mathematical communication skills following the delivery of treatments to each cohort. Once instruction concluded, both groups completed a posttest to measure these proficiencies. Descriptive statistics summarizing the posttest outcomes for the experimental and control groups are detailed in Table 2.

Table 2. Descriptive Statistic of Posttest Results

Group	N	Mean	Standard Deviation
Control Class (Conventional)	26	51,92	13,422
Experimental Class (PBL Model)	30	61,50	15,489

Based on the posttest results, the experimental class obtained a higher mean score (61.50) than the control class (51.92). This difference indicates better posttest performance in mathematical communication skills in the experimental class. However, the mean score alone does not indicate a statistically significant mastery of mathematical communication skills. The statistical significance of the difference was therefore examined through an independent samples t-test.

Observation of Learning Implementation

Based on the monitoring of the teaching process, the implementation of the PBL model combined with a scientific approach proceeded exceptionally well. Three independent observers documented execution rates of 82%, 91%, and 91%, respectively, yielding a mean score of 88% that places it within the "very good" category. This finding indicates that all learning syntaxes were implemented in accordance with the learning design.

Table 3. Results of Observation of Learning Implementation

Observe	Score	Criteria
Observer 1	82%	Very Good
Observer 2	91%	Very Good
Observer 3	91%	Very Good
Average	88%	Very Good

Normality Test

Data normality was tested using the Shapiro-Wilk test via SPSS. The decision criterion was based on a significance level of 0.05. If the significance value was greater than 0.05, H_0 was accepted, indicating that the data were normally distributed.

Table 4. Normality Test Results (Shapiro-Wilk)

		Shapiro-Wilk		
Variabel	Class	Statistic	Df	Sig.
Score	Class X8	0.937	30	0.076
	Class X6	0.944	26	0.167

According to Table 4, the results show significance values of 0.076 for Class X-8 and 0.167 for Class X-6, both of which are greater than 0.05. Based on the test results, students' mathematical communication data from both groups demonstrated a normal distribution, thereby satisfying a necessary condition for conducting the hypothesis test.

Homogeneity Test

Before the treatment was administered, preliminary data were analyzed to determine whether the experimental and control classes had equal variances. The homogeneity test was conducted to ensure that the two classes had comparable variance before the implementation of different learning treatments. The homogeneity of variance was tested using Levene's test with SPSS at a significance level of 0.05. The data were considered homogeneous if the significance value was greater than 0.05, while a significance value below 0.05 indicated that the data were not homogeneous.

Table 5. Homogeneity Test Results

			Levene statistic	Df1	Df2	Sig.
Posttest result	(Based on Mean)		3.864	1	66	0.054

As shown in Table 5, the homogeneity assessment produced a significance score of 0.054, which is greater than the 0.05 level. Therefore, the variance of the mathematical communication scores between the experimental and control cohorts was confirmed to be homogeneous, successfully meeting the prerequisite condition for hypothesis testing.

Hypothesis Test

After the normality and homogeneity of variance assumptions were successfully met, the study's hypothesis was examined using an independent samples t-test at a significance level of 0.05 to determine the impact of applying the PBL model.

Table 6. Hypothesis Test Results (*t-test for Equality of Means*)

		T-test for Equality of Means				
		t	df	Sig. (2-tailed)	Mean difference	Std. error difference
Score	Equal variances assumed	2.453	54	0.017	9.57692	3.90363

Based on the data displayed in Table 6, the analysis produced a two-tailed significance value of 0.017, falling beneath the pre-established alpha level of 0.05. This outcome led to the rejection of H_0 and the acceptance of H_1 . Consequently, these results demonstrate that incorporating the PBL model with a scientific approach exerts a statistically significant impact on students' mathematical communication proficiencies.

The implementation of PBL integrated with a scientific approach achieved an average observation score of 88%, categorized as “very good.” The observation results from three observers were 82%, 91%, and 91%, respectively. This indicates that the learning stages were implemented appropriately, including problem orientation, student organization, investigation guidance, development and presentation of solutions, and

evaluation of the problem-solving process (Ariyana et al., 2018). Good implementation of the learning stages supported an active learning environment in which students were engaged in problem solving and discussion (Ardianti et al., 2021).

The use of PBL combined with a scientific approach encouraged students to take an active role throughout the learning process. In learning statistics, students were engaged in identifying relevant information, discussing alternative solutions, applying mathematical representations, and presenting their results. Such activities provided students with opportunities to convey their mathematical ideas and reasoning. Through observing and questioning activities, students identified important information and expressed mathematical ideas related to the problems. During investigation and associating activities, students represented mathematical ideas through mathematical symbols, tables, pictures, and graphs. When presenting their solutions, students had opportunities to explain their procedures and communicate their mathematical reasoning. These learning experiences directly corresponded to the mathematical communication indicators assessed in this study.

The posttest findings showed that the experimental class achieved a higher average score of 61.50 compared with 51.92 in the control class. The independent samples t-test yielded a significance value of 0.017, which was below the 0.05 significance level, and the obtained t-value of 2.453 was greater than the critical t-value. These results indicate a statistically significant difference in mathematical communication posttest scores between the two groups following the respective instructional treatments.

The findings are in accordance with previous research. Ghaida and Fatimah (2024) and Wati and Loviana (2022) found that PBL integrated with a scientific approach was associated with better mathematical communication skills. Other studies have also reported positive findings regarding the use of PBL with a scientific approach in improving mathematical problem-solving abilities and mathematics learning outcomes (Hasriyani et al., 2022; Panggabean et al., 2025). These positive impacts of PBL on expanding students' mathematical understanding and analytical thinking are also strongly supported by Saefuloh et al. (2023), who verified that PBL improves students' systemic mathematical competencies. The present study extends these findings by demonstrating the effectiveness of PBL integrated with a scientific approach in enhancing mathematical communication skills among tenth-grade senior high school students studying statistics.

CONCLUSION

This study aimed to investigate the effect of Problem-Based Learning (PBL) integrated with a scientific approach on the mathematical communication skills of tenth-grade senior high school students. Based on the posttest results, the experimental class obtained a higher mean score (61.50) than the control class (51.92). The independent samples t-test showed a significance value of 0.017, which was lower than the 0.05 significance level, indicating a statistically significant difference between the two classes. Therefore, the implementation of PBL integrated with a scientific approach had a significant positive effect on students' mathematical communication skills in the context of this study.

These findings demonstrate that the PBL model integrated with a scientific approach can serve as an effective alternative for enhancing students' mathematical communication skills. However, the study was conducted in a single school and employed a posttest-only control group design. Therefore, further research is recommended to involve a wider sample and use a research design that includes pretests and posttests to obtain more comprehensive results.

DECLARATIONS

- Author Contribution : BS: carried out the research, performed the data analysis, and drafted the manuscript. CEN & SCN: provided supervision, offered academic direction, reviewed the manuscript, and endorsed the final version for publication.
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- Conflict of Interest : The authors declare no conflicts of interest regarding the publication of this article.
- Additional Information : This study uses data from SMA Negeri 1 Purwonegoro.

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