

EXPLORING THE EFFECT OF PROBLEM BASED LEARNING WORKSHEETS ON STUDENTS' MATHEMATICAL COMMUNICATION

Selvi Loviana^{1*}, Tina Yunarti²

^{1,2} Universitas Lampung, Bandar Lampung, Indonesia

^{1*} Universitas Islam Negeri Jurai Siwo Lampung, Metro, Indonesia

* Corresponding author. Jalan Anak Tuha, 34114, Metro, Indonesia

E-mail: selviloviana1112@gmail.com¹

tina.yunarti@gmail.com²

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ABSTRACT

Mathematical communication skills are essential for students to develop in mathematics learning. These skills involve expressing ideas, explaining problem-solving procedures, and constructing logical arguments systematically. However, observations and interviews at SMP Negeri 9 Metro revealed that students' mathematical communication skills remain low. They struggle to write mathematical models, represent problems visually, and convert contextual situations into appropriate mathematical symbols or notations. This condition is further aggravated by teacher-centered learning and using less engaging and contextual media. This study examines the effectiveness of Student Worksheets (LKPD) based on Problem-Based Learning (PBL) in improving students' mathematical communication skills. The research employed a quasi-experimental method with a post-test only control group design. The sample consisted of two eighth-grade classes selected through purposive random sampling: class VIII F, which used the LKPD before revision, and class VIII D, which used the LKPD after revision. The research instrument was a mathematical communication test, while the data were analyzed using the Mann-Whitney test. The results showed no significant difference in students' mathematical communication skills between the classes before and after the revision of the PBL-based LKPD, with a significance value of 0.876 (> 0.05). These findings indicate that the revised LKPD has not yet fully incorporated elements that support communication skills, such as tasks promoting discussion, written and oral expression, and adequate visual representation. Therefore, future development of LKPD should integrate real-life contexts, engaging visualization, and collaborative activities to enhance students' ability to communicate mathematical ideas.

Keywords: mathematics communication; problem based learning; worksheets

ABSTRAK

Keterampilan komunikasi matematis merupakan kompetensi penting yang harus dimiliki peserta didik dalam pembelajaran matematika. Keterampilan ini mencakup kemampuan mengungkapkan ide, menjelaskan prosedur pemecahan masalah, serta menyusun argumen logis secara sistematis. Namun, hasil observasi dan wawancara di SMP Negeri 9 Metro menunjukkan bahwa kemampuan komunikasi matematis peserta didik masih rendah. Mereka mengalami kesulitan dalam menuliskan model matematika, merepresentasikan masalah secara visual, serta mengubah situasi kontekstual menjadi simbol atau notasi yang sesuai. Kondisi ini diperburuk oleh pembelajaran yang berpusat pada guru serta penggunaan media yang kurang menarik dan kontekstual. Penelitian ini bertujuan menguji efektivitas Lembar Kerja Peserta Didik (LKPD) berbasis Problem Based Learning (PBL) untuk meningkatkan kemampuan komunikasi matematis. Metode penelitian yang digunakan adalah eksperimen semu dengan desain post-test only control group. Sampel terdiri dari dua kelas VIII yang dipilih melalui purposive random sampling, yakni kelas VIII F sebagai kelompok yang menggunakan LKPD sebelum revisi dan kelas VIII D sebagai kelompok yang menggunakan LKPD setelah revisi. Instrumen penelitian berupa tes kemampuan komunikasi matematis, dengan analisis data menggunakan uji Mann-Whitney. Hasil penelitian menunjukkan tidak terdapat perbedaan signifikan

antara kemampuan komunikasi matematis peserta didik pada kelas sebelum dan sesudah revisi LKPD berbasis PBL, dengan nilai signifikansi 0,876 ($> 0,05$). Temuan ini menunjukkan bahwa revisi LKPD belum optimal dalam memuat unsur yang mendukung pengembangan komunikasi matematis, seperti penugasan diskusi, penyampaian ide secara tertulis maupun lisan, dan representasi visual. Oleh karena itu, pengembangan LKPD selanjutnya perlu mempertimbangkan integrasi konteks nyata, visualisasi menarik, serta aktivitas kolaboratif agar peserta didik dapat berlatih mengomunikasikan ide matematika secara efektif.

Kata kunci: komunikasi matematika; lembar kerja peserta didik (LKPD); problem based learning



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Introduction

Education is one of the essential keys to achieving a better quality of life, particularly in terms of development. The 2023–2024 Human Development Report (HDR) emphasizes that human capacity in facing global uncertainty depends significantly on communication skills (UNDP, 2024). The 2025 United Nations Development Programme (UNDP) report highlights the importance of holistic human development through equitable and inclusive improvements in education quality. One primary concern raised in the report is the persistent disparity in access to and quality of education, especially regarding critical thinking and communication skills that are vital in responding to global challenges and technological advancements.

The decline in student performance in the 2022 PISA results can be attributed to six main factors: the impact of the pandemic, curriculum-related issues, individual student factors, limited educational resources, student engagement and motivation, and parental involvement in the learning process (Wijaya, Hidayat, Hermita, Alim, & Talib, 2024). An overly dense curriculum that provides limited opportunities for exploration and discourse may impede students' ability to articulate mathematical ideas meaningfully. Consequently, enhancing mathematical communication skills is critical in improving the overall quality of mathematics education at the national level.

Although Metro City is recognized as an educational hub in Lampung Province, challenges in the quality of mathematics education at the junior high school (SMP) level remain evident. Observations and interviews at SMP Negeri 9 Metro reveal that students' motivation to learn mathematics is low, and their mathematical communication abilities are still suboptimal. UNDP emphasizes that strengthening communication and contextual problem-solving skills is crucial to improving 21st-century learning quality and is a key indicator of human development progress.

In Metro City, educational attention spans from early childhood to higher education. At the junior high school level, students undergo various development stages and need strong learning motivation. Mathematics is a subject that supports the development of students' abilities for the future.

Mathematics teachers at SMP Negeri 9 Metro report that the topic of SPLDV is among the most challenging for students. Students often struggle with writing variables and require a contextual learning approach. SPLDV often challenge students because they require understanding complex concepts and clear logical

thinking. Students need to translate real-life problems into correct mathematical models, understand how two equations with two variables relate, and use different methods to solve them, such as substitution, elimination, and graphing. Mistakes in any step can affect the final answer, so students must work carefully. Additionally, students must connect their solutions back to the original problem, which can be difficult. Because of this, effective teaching strategies are important to help students understand and apply these concepts correctly. Fitriani & Amelia (2021), the most common mistakes students make in solving SPLDV are in the indicators of creating mathematical models and determining solutions using the graphing method. Students have difficulty translating word problems into mathematical models and drawing graphs. Sartini (2022), the topic of SPLDV is frequently delivered through word problems. Consequently, many students have difficulty understanding the material, with some failing to grasp it.

Sugandi & Bernard (2018) affirm that contextual learning enhances students' communication and understanding. Students typically access content from textbooks or worksheets provided by publishers, which are often visually unappealing. As a result, students struggle to grasp mathematics lessons fully because the materials do not match their learning needs. Rahmi, Nadia, Hasibah, & Hidayat (2017) Teachers should create opportunities within mathematics instruction that allow students to enhance their mathematical communication skills, as these experiences are essential for developing such competencies. Lubis, Meiliasari, & Rahayu (2023), mathematical communication refers to students' ability to convey mathematical ideas using language, symbols, or notations, allowing them to comprehend, interpret, and represent relationships and solve contextual problems through mathematical models, both verbally and in written form. Students with poor mathematical communication skills will have difficulty understanding the material, ultimately affecting their learning outcomes.

Contextual elements in mathematics learning can be integrated through illustrative examples, problem situations, or practice tasks, encompassing routine and non-routine question types (Fajri, Hartono, & Hiltrimartin, 2022). Mahmud (2017), teachers must provide challenging tasks that are still achievable and manageable for students to build self-confidence. PBL-based LKPD aims to make mathematics learning more enjoyable and motivating for students while enhancing their communication skills. Mathematical communication includes both verbal and written components. According to Hodiyanto (2017), verbal communication encompasses discussion and explanation, whereas written communication involves expressing mathematical ideas through diagrams, graphs, tables, equations, and students' language. Teachers must foster mathematical communication skills during instruction to equip students with these abilities.

Experts widely recognize mathematical communication as a crucial skill in mathematics learning, serving both as a tool and a language. It is also associated with developing a positive attitude in students, enabling them to apply mathematics meaningfully for themselves and others (Indriani & Noordiana, 2022). Ramadhan, Arliani, Purbaningrum, & Azizah (2023), communication skills are among the core competencies emphasized in 21st-century education. Hartati, Abdullah, & Haji (2017), mathematical communication skills are defined as students' capacity to convey mathematical concepts or understanding verbally or in written form, with

or without visual or technological media. This skill is crucial in helping students understand problems and find appropriate solutions. Inability to communicate effectively can hinder the comprehension of concepts and problem-solving processes. Therefore, effective communication facilitates accurate problem representation and supports success in problem-solving. According to Tong, Uyen, & Van Anh Quoc (2021), three important standards in mathematical communication must be understood and applied: (1) students formulate and develop their ideas in oral and visual forms; (2) students communicate their ideas clearly and systematically to teachers and peers; and (3) students review, assess, and solve problems through collaboration with classmates.

Hidayat & Aripin (2023), defined as the ability to communicate mathematical the capacity to express logical thought processes in a clear, coherent, and understandable manner, translate real-life situations into simpler mathematical models, and effectively articulate mathematical ideas or concepts. These communication skills are still considered low because students cannot effectively communicate mathematical ideas during mathematics learning. Rahmalia, Rianti, Hajidin, & Bi. Ansari (2020), highlight that mathematical communication is a strategic competency that supports psychological and affective development and contributes to the effectiveness of mathematics learning. Pasani & Amelia (2025), students' understanding can be enhanced by facilitating their mathematical communication skills, which include developing the ability to express logical ideas and mathematical concepts and using symbols accurately. So, students' mathematical communication skills both oral and written promote activeness and function as tools for thinking and communication that must be continuously developed and are strongly endorsed by mathematics education experts.

Well-designed LKPD can contain tasks that actively engage students. According to Widodo et al. (2023), worksheets are critical to educational research and remain relevant in present and future academic contexts. LKPD can be a primary student, act as a learning resource in addition to the teacher, and serve as the primary focus of learning activities in the classroom. Yulisra et al. (2022), student worksheets aim to enable students to understand and discover concepts or learning materials independently, individually, or in groups, as an innovation in instructional material development. This is due to the limitations of textbook activities, which often make it difficult for students to comprehend the learning content. Students are encouraged to learn independently rather than relying solely on teachers. Setyaningrum & Sari (2023), the worksheet developed based on the PBL model can enhance student activity and direct involvement in problem-solving activities. So LKPD helps reinforce conceptual understanding by providing exercises and materials that develop students' mathematical reasoning. Utilizing LKPD in learning offers a significant opportunity to produce high-achieving students.

A common factor contributing to junior high school students' limited mathematical communication skills is the prevalence of teacher-centered approaches during classroom instruction. Evidence from teacher and student interviews and results from communication skill assessments support this observation. Conversely, implementing group-based mathematics instruction fosters greater student engagement and promotes the use of communication skills to enhance understanding and task completion. (Naja & Sa'o, 2023) state that the

Problem-Based Learning model is a constructivist approach rooted in real-world situations, emphasizing problem-solving processes that shape mathematical thinking and critical thinking skills. Ndole & Ana (2021) argue that, PBL promotes active student involvement through collaborative group work, where students discuss, exchange ideas, and draw on prior experiences to formulate problem solutions.

Rohmatulloh, Pujiastuti, & Fathurrohman (2022), PBL enhances students' mathematical skills when applied in the classroom. Usman, Jamaan, Arnellis, Permana, & Zafirah (2025), PBL model positions students as the focal point of the learning process. It facilitates students in solving mathematical problems connected to real-life contexts and enhances their interest and motivation in learning. Rihayati, Purnomo, & Pamenan (2023), PBL model uses problems as a starting point to stimulate students' active thinking, to enable them to solve every problem encountered during the learning process. Thus, PBL can significantly improve students' mathematical communication abilities. Traditional one-way instructional methods and unengaging learning media, such as worksheets consisting only of static texts, further widen the gap between students' potential and target competencies. Therefore, using Problem-Based Learning based LKPD is a recommended instructional strategy, as it stimulates students' communication, collaboration, and creativity, aligning with the human capacity development framework outlined by UNDP.

There remains a gap in research on evaluating LKPD designed using the PBL approach to improve students' mathematical communication skills. Combining LKPD with the PBL model helps students solve real-world problems, be more active, collaborate in testing ideas, and improve their math communication. PBL-based LKPD is expected to build students' math skills, especially communication. Since PBL has been shown to enhance communication, this study aims to evaluate how effective LKPD designed with PBL improves students' ability to communicate mathematical concepts.

Based on this overview, integrating LKPD with the PBL model allows students to engage with real-world problems, become more active, collaborate in hypothesis testing, and enhance their mathematical communication abilities. The student worksheets used in this study were specifically designed to include tasks that support the development of students' communication skills. These tasks are presented as contextual problems from everyday life, sometimes incorporating simple games to make the learning process more enjoyable. Such games provide variations in problem-solving so that students do not feel pressured when completing tasks.

The tasks are completed collaboratively through the PBL model, allowing students to exchange information and practice communication skills with their peers. In addition, classroom presentations allow students to communicate the results of their discussions and task solutions to peers and the teacher, while practicing appropriate wording in their explanations. The use of PBL-based LKPD is expected to foster students' competencies in mathematics, especially communication skills. Given that PBL has been shown to improve communication, the aim of this study to evaluate the effectiveness of LKPD designed through the PBL

approach with the aim of improving students' ability to communicate mathematical concepts effectively.

Research Methods

This study employed a quasi-experimental design with a post-test only control group approach. The research stages included: (1) problem identification and literature review to find research gaps, (2) design of the Problem-Based Learning (PBL)-based student worksheet (LKPD) focusing on developing mathematical communication skills, (3) validation of the LKPD by subject matter and instructional experts to ensure content feasibility and alignment with objectives, (4) implementation of the LKPD in the classroom using the PBL model, (5) data collection through various instruments, and (6) analysis and evaluation of the research results.

The research subjects were eighth-grade students at SMP Negeri 9 Metro, with two classes sampled: class VIII D as the experimental group using the revised PBL-based LKPD, and class VIII F as the control group using the previous version of the LKPD. Purposive sampling was used based on equal initial abilities and student characteristics. Each class consisted of 25 students.

The research instruments included: (a) LKPD validation sheets completed by subject matter and instructional experts, (b) a mathematical communication skills test instrument that had been trial to assess reliability, difficulty level, and item discrimination, (c) observation sheets for learning implementation and student engagement, (d) questionnaires to measure student perceptions and satisfaction with the learning process, (e) structured interviews with teachers and students to explore experiences and challenges during learning, and (f) documentation in the form of photos, videos, and lesson notes as evidence of implementation. Data was collected over seven learning sessions, with observations and completion of other instruments following the learning schedule.

Quantitative data from the mathematical communication skills test were analyzed using the Mann-Whitney U test to compare the results between the experimental and control groups. Qualitative data from interviews and observations were analyzed descriptively using a thematic analysis approach to identify patterns, themes, and findings related to the learning experience and the effectiveness of the PBL-based worksheet.

Results and Discussion

The learning process in this study consisted of seven sessions conducted using the PBL model. These sessions were held twice weekly Mondays from 08:00 to 09:20 WIB and Wednesdays from 08:40 to 10:00 WIB. During the sessions, students worked in small groups to complete the LKPD, which contained problem-based tasks. Each group consisted of 4 to 5 students, with at least one student possessing a higher ability level than the others. This structure facilitated peer support and enhanced students' communication skills, with the teacher acting as a facilitator or tutor.

The LKPD used in this study was first reviewed with academic supervisors and then validated by subject matter experts, design experts, and media experts. Based on Piaget's theory, students in Grade VIII are generally at the formal

operational stage, as they are typically over 12 years old. Therefore, they can solve problems and construct knowledge, particularly in mathematics, from the tasks provided. Students demonstrated an understanding of the differences between Single Linear Equation and SPLDV in the first session of the LKPD.

Although the PBL model is implemented, variations in student participation levels indicate that some students may require more in-depth guidance in group sessions. Therefore, additional training for teachers in facilitating group discussions and encouraging more equitable participation is essential. Developing better PBL facilitation skills can help ensure that all students actively participate and can develop their communication skills effectively.

Some revisions were needed for the LKPD, particularly in the first and fifth sessions, including improvements to the wording of the problems. In contrast, the worksheets for the other sessions were well-understood by the students. The PBL-based LKPD successfully stimulated students' mathematical communication skills, which emerged while completing the worksheet tasks. In general, most students displayed curiosity, flexibility, strategic thinking, a desire for truth and understanding, and moments of uncertainty, which contributed to communicative thinking, particularly during group discussions. Metacognitive indicators and uncertainty were observed when the teacher posed follow-up questions or sought clarification on students' responses.

Students' mathematical communication skills were reflected in the responses from class VIII F, where several students could write symbols and model mathematical problems accurately. The indicator related to expressing and illustrating mathematical ideas through diagrams or other mathematical models showed the highest percentage (84.62%), with a maximum score of 468 and an achievement score of 396. However, the indicator involving the translation of situations, images, or diagrams into mathematical language, symbols, or models had the lowest percentage (62.82%), with a maximum score of 156 and an achievement score of 123. This indicates that students struggled with this indicator and required further teacher guidance. The average percentage score for all indicators was 76.96%.

The highest post-test score in class VIII F was 9.6, indicating that one student had fully mastered the mathematical communication skills. Meanwhile, the lowest score was 4.1, shared by two students, showing that some students still had difficulties fully developing their mathematical communication ability. Table 1 presents the data on students' mathematical communication skills.

Table 1. Student mathematical communication skill data.

Class	Number of Students	Minimum Score x_{min}	Maximum Score x_{maks}	Average Score \bar{x}
Exsperiment	25	4,1	9,6	7,6
Control	25	3,7	100	6,6

Table 1 presents data on students' mathematical communication skills in the experimental and control classes. The experimental class, which used the revised PBL-based LKPD, demonstrated a slightly higher average ability than the control

class, which used the pre-revision LKPD. The calculation results in Table 2 show the Normality Test using SPSS 17 for the pre-revision and post-revision classes.

Table 2. Normality test results

		Pre-Revision Class	Post-Revision Class
N		25	25
Normal Parameters ^{a,b}	Mean	76.96	76.52
	Std. Deviation	18.286	17.835
	Most Extreme Differences		
	Absolute	.163	.173
	Positive	.114	.137
	Negative	-.163	-.173
Kolmogorov-Smirnov Z		.813	.865
Asymp. Sig. (2-tailed)		.523	.442

Table 2 presents the normality test results using the Kolmogorov-Smirnov method for the pre-revision and post-revision classes. The significance values obtained were 0.523 for the pre-revision class and 0.442 for the post-revision class, which are greater than 0.05. These results indicate that the data in both groups are normally distributed. Meeting the normality assumption allows the researcher to proceed with subsequent statistical analyses. Subsequently, a homogeneity test was conducted using SPSS 17. The results are presented in Table 3.

Table 3. Homogeneity test results

Levene Statistic	df1	df2	Sig.
5.200	6	13	.006

Based on Table 3, the homogeneity test results show a significance value of 0.006, less than 0.05. This indicates that the data do not meet the assumption of equal variances between the groups. Therefore, the researcher could not use a parametric test such as the independent samples *t*-test and instead applied a non-parametric test, the Mann-Whitney U test, to compare students' mathematical communication skills. This adjustment ensured that the analysis remained valid and that the conclusions were not biased due to violations of statistical assumptions. The results of the Mann-Whitney U test using SPSS 17 are shown in Table 4.

Table 4. Mann-whitney u test results

	Score
Mann-Whitney U	304.500
Wilcoxon W	629.500
Z	-.156
Asymp. Sig. (2-tailed)	.876

Table 4 presents the results of the Mann-Whitney U test, showing an Asymp. Sig. value of 0.876, which is greater than 0.05. This indicates no statistically significant difference in mathematical communication skills between the pre-

revision and post-revision PBL-based LKPD groups. These results suggest that the revisions did not substantially enhance students' communication abilities, underscoring the need for further improvements that explicitly support mathematical communication.

Subsequently, a proportion test was conducted to determine the effectiveness of the LKPD. The testing criterion was $Z_{\text{calculated}} \geq Z_{\text{table}}$ at a 0.05 level of significance, which would result in rejecting H_0 . However, the findings showed that fewer than 70% of students scored above the minimum passing grade, indicating that the LKPD has not yet been effective for students.

This research indicates that some questions need revision to improve student understanding. This underscores the importance of retesting LKPD before widespread use. Researchers or LKPD developers need to continuously evaluate existing questions and consider their level of difficulty and delivery methods. Homework that focuses more on translating situations into mathematical representations or challenging students to explain problem-solving processes verbally can be introduced.

The findings agree with Maulidia et al. (2019), who showed that PBL supports meaningful learning by integrating knowledge and skills in real-life contexts. This study also supports (Rahmawati & Cholily, 2023) who found that PBL-based worksheets can improve mathematical communication if well-developed and implemented. Challenges like student participation and teacher facilitation are common issues noted in prior research, confirming the need for ongoing teacher training and better instructional materials.

Results showing low scores among some students in mathematical communication skills indicate the need for a more holistic assessment. Qualitative assessment methods, such as interviews or observations during group discussions, can provide a complete picture of students' communication skill development. These methods can complement test results and provide a deeper understanding of students' understanding.

The LKPD used in this study contained problems that gradually increased in difficulty. Mathematics learning through PBL-based LKPD made students more active. Student participation varied across the seven learning sessions. Two high-achieving students consistently remained active in each session. The problem-based tasks in the LKPD helped some students improve their communication skills.

To achieve optimal results, the implementation of PBL should be continuously evaluated and further refined. Incorporating structured reflection sessions for students after each lesson can provide opportunities to assess their communication effectiveness and identify areas for improvement. Such reflective practices can enhance student engagement in learning and foster greater motivation to develop their communication skills.

The study results showed no significant improvement in students' mathematical communication skills for several reasons. First, student participation varied widely, with some needing more guidance during group work. Second, revisions to the student worksheet were not fully effective, especially in some sessions where problem wording was unclear. Third, students found translating situations or diagrams into mathematical language challenging. Finally, teachers needed better skills to facilitate group discussions and encourage equal

participation. Together, these factors limit the effectiveness of the PBL-based LKPD in improving communication skills.

This study's strengths include using a Problem-Based Learning model that matches the students' cognitive development stage and combining quantitative and qualitative data for a fuller understanding. The research instruments were validated and reliable, and the data analysis was appropriate for the data type.

However, weaknesses include uneven student participation and incomplete improvements in the worksheet. Teachers' facilitation skills also need enhancement to support student engagement better. Additionally, the study did not track the long-term effects of the learning model.

Theoretically, this research adds knowledge about using PBL-based worksheets to improve math communication in junior high students. It highlights the crucial role of teachers as facilitators in promoting group communication. Practically, it offers guidance for curriculum developers and teachers to create worksheets suited to students' needs and stresses the importance of teacher training in PBL methods. The study also suggests adding reflection sessions to help students improve communication skills. Overall, it contributes to developing more engaging, interactive, and effective math learning strategies focused on communication skills.

Conclusion and Suggestion

The measurement of mathematical communication skills in this study was carried out in two ways. First, quantitatively through written tests that assessed students' abilities to use mathematical symbols, language, and diagrams. Second, qualitatively through observations during group discussions, interviews with students and teachers, and documentation such as photos and videos. Combining these two methods helped provide a complete picture of students' mathematical communication skills from test results and how they communicate during learning.

This study evaluated the effectiveness of PBL using revised student worksheets to improve students' ability to communicate mathematical concepts effectively. The findings showed that implementing PBL-based worksheets had a positive but insignificant effect on students' mathematical communication skills. While students showed increased curiosity, strategic thinking, and engagement during group activities, challenges remained, particularly in translating real-world problems into mathematical language. Variations in student participation and the need for clearer worksheet problems impacted the overall effectiveness. Teacher facilitation was crucial in supporting student communication, highlighting the importance of ongoing teacher training. Although the revised worksheets led to slightly higher communication scores than the previous version, further improvements and continuous evaluation are needed to realize the benefits of PBL in mathematics learning fully. The worksheets can be more engaging by enriching them with more appealing visualizations, integrating interactive media, or considering varying problem difficulty levels according to students' cognitive levels.

Furthermore, developing more contextualized problems that stimulate classroom discussion can also increase the effectiveness of the worksheets. One possible cause of the lack of effectiveness of PBL is inconsistent or inadequate implementation. Researchers can focus more on teacher training or external

support to ensure that the PBL model is implemented appropriately and consistently across classes. Effective PBL implementation requires teachers to deeply understand collaboration, discussion, and group management strategies, which must be applied consistently. For future research, it is recommended that the worksheets be refined further, mainly focusing on problem clarity and scaffolding translation skills, and providing additional training for teachers in PBL facilitation. Longitudinal studies could also assess the long-term effects of PBL-based learning on students' mathematical communication abilities.

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