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THE EFFECT OF A PROBLEM-BASED LEARNING MODEL ASSISTED BY INTERACTIVE E-LKPD ON STUDENTS' MATHEMATICAL COMMUNICATION SKILLS

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Abstract: This study aims to determine the effect of a problem-based learning model assisted by interactive E-LKPD on students' mathematical communication skills. The research design used in this study was a randomized pretest-posttest control group design. The study population was all students in grade VIII of SMP Negeri 5 Bandar Lampung in the 2024/2025 academic year, which was distributed in nine classes. The cluster random sampling technique classes VIII.5 and VIII.7 were selected as research samples. The data analyzed in this study were quantitative data obtained through a description-based test on SPLDV material. The gain score data in the experimental class was not normally distributed, and the control class was normally distributed, so the data analysis in the study used the Mann-Whitney U test with a significance level of $\alpha = 0.05$. The results of the data analysis showed that the median date of the increase in the mathematical communication skills of students with the problem-based learning model assisted by interactive E-LKPD was higher than the median date of the increase in the score of mathematical communication skills of students in conventional learning. Based on the research results and discussion, it is concluded that the problem-based learning model assisted by interactive E-LKPD affects students' mathematical communication skills.

Keywords*:* communication skills; effect; E-LKPD; problem-based learning

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Introduction

The development of science and technology (IPTEK), which is so fast and becomes more competitive, causes the need for quality human resources (HR) to increase (Permatasari *et al*., 2020). According to Sudarsana (2015), one of the factors that affects the quality of human resources (HR) is education, because education has a vital role in the life of the nation and state, especially in efforts to create quality human resources. Therefore, one of the strategies that can be used to improve the quality of human resources in Indonesia is the education system (Anggraini *et al*., 2016).

Education can be pursued formally, non-formally, and informally. In formal education, mathematics is one of the subjects that must be taught at every level. This is based on PP No.4 of 2022, article 40, paragraph 2 concerning the Primary and Secondary Education Curriculum, which explains that mathematics is one of the compulsory subjects that must be taught at every level of primary school education through high school education.

Mathematics is one of the sciences that has an important role in various aspects of life, especially in developing a human mindset to think critically, logically, and scientifically (Riskyka & Syafitri, 2022). In addition, mathematics plays an important role in supporting personal development from various aspects such as social, economic, technology, architecture, and so on (Hodanova & Nocar, 2016). In learning, mathematics teaches students to use mathematical modeling, tables, diagrams, or mathematical symbols in solving problems related to numbers in everyday life, thus training students to think critically, logically, and systematically (Noer & Gunowibowo, 2018). Thus, based on the description above, mathematics is one of the important sciences because it plays an important role in scientific disciplines and advances human thinking.

The purpose of learning mathematics explained in BSKAP (2024) is so that students can have the ability to (1) understand mathematical concepts, (2) use reasoning on patterns and properties, (3) solve problems, (4) communicate ideas through symbols, tables, diagrams, or other media to clarify situations or problems, (5) link learning materials in the form of facts, concepts, principles, operations, and mathematical relations in a field of study, across fields of study, across fields of science, and with life (6) have an attitude of appreciating the benefits of mathematics in everyday life. To achieve the goals of learning mathematics, one of the abilities that every student must have is mathematical communication skills.

Mathematical communication skills are the ability of students to express their mathematical ideas through language, notation, or mathematical symbols, so that they can understand, interpret, and solve contextual problems into mathematical models both orally and in writing (Lubis *et al*., 2023). In addition to this, communication helps students in connecting abstract ideas and language with mathematical symbols, so that students are allowed to convey their ideas orally, in writing, pictures, or graphs, and communication also provides space for students to discuss and talk about mathematics (Astuti & Leonardo, 2015). In line with the opinion of Sritresna (2017), through communication, students can develop a better understanding of mathematical concepts and strengthen their skills in solving mathematical problems.

However, in reality, in the field, students' mathematical communication skills in Indonesia are still relatively low. Based on the results of the international assessment of the Programme for International Student Assessment (PISA) by the Organization for Economic Cooperation and Development (OECD) in 2022, Indonesia's ranking in mathematics was ranked 68th out of 81 countries with a score of 366 which was far from the average international score of 472. According to Sari (2015); Noviyana *et al*., (2019) one of the factors that cause the low mathematics achievement of Indonesian students is the low ability of students in the realm of applying, this occurs because of students' confusion in presenting mathematical ideas or ideas in the form of symbols, graphs, tables or other media to clarify mathematical problems. The ability to present mathematical ideas in symbols, graphs, or tables is closely related to students' mathematical communication skills (Wulandari *et al*., 2018).

Low mathematical communication skills also occur in SMP Negeri 5 Bandar Lampung students. Based on the results of the analysis of questions that test the mathematical communication skills of class IX students, it is known that most students have difficulty in solving contextual problems, especially in changing the form of story problems into the form of mathematical equations, representing mathematical models in the form of images, graphs, tables and diagrams. Based on the answers from students, 80% (20 out of 26 students) have not been able to answer the questions correctly. There are several student errors, including students who have not been able to present data from tables into percentages correctly, are inaccurate in presenting data in the form of pie charts, and are less able to explain their mathematical ideas in writing clearly and in detail.

Many factors certainly cause students to have low mathematical communication skills. According to Corebima *et al*. (2020), low communication skills are due to learning situations that have not emphasized the problem-solving aspect. The majority of learning that is usually applied so far is monotonous and teacher-dominated learning activities, causing students to be given less opportunity to express their own opinions independently (Oktaviarini, 2015). According to Hafidloh *et al*. (2020),

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students' mathematical communication can be better if a learning model is applied following the situation and conditions of students and their learning environment. The selected learning model must be able to develop students' ability to interpret a problem into mathematical form correctly. One of the learning models that can improve students' mathematical communication skills and active learning conditions is problem-based learning (Alzianina *et al*., 2016; Kanah & Mardiani, 2022).

Problem-Based Learning (PBL) is one of the models that can provide active learning conditions for students by directing students to solve a problem together (Yanti, 2017). PBL uses problems as a starting point in learning, allowing students to gain a more realistic learning experience (Syamsidah & Hamidah, 2018; Tanjung & Nababan, 2019). Problems in PBL are emphasized on contextual problems often found by students in everyday life (Bahriah & Yunita, 2024). PBL encourages students to explain and present their solutions, ask questions, participate in discussions, use mathematical representations, and reflect on their problem-solving, thus helping them develop mathematical communication skills (Salsabilla *et al*., 2023). Based on research by Kumala (2019), applying the PBL model can help improve students' mathematical communication skills. Then, it was strengthened by Corebima *et al*. (2020), who stated in their research that the PBL model is very effective in improving students' mathematical communication skills.

There are still weaknesses in applying the PBL model, so learning media is needed to help students and support this PBL learning process (Ambarwati, 2021). The PBL model can be applied more optimally with the help of technology-based learning using interactive worksheets to improve students' mathematical communication skills (Manurung *et al*., 2024). LKPDs that utilize electronic media are often called interactive E-LKPDs (Suwastini, 2022). Interactive E-LKPD encourages students to be active in learning and provides convenience in learning (Prastika & Masniladevi, 2021).

The use of interactive E-LKPD based on liveworksheets can provide learning variations to students so that learning is not dull, because various kinds of tasks can be arranged in liveworksheet-based E-LKPD in the form of multiple choice, matching, pairing, drop-down, open questions, tick, drag and drop, and other forms of tasks according to the needs of educators (Widyaningrum *et al*., 2020). Liveworksheets can turn traditional worksheets that can be printed as documents (PDF and JPG) into interactive online exercises because they can contain videos, images, and audio (Widiyani & Pramudiani, 2021).

The PBL model, assisted by interactive worksheets, can improve mathematical communication skills. This is in line with the results of research by Manurung *et al*. (2024), which states that the PBL model assisted by interactive student worksheets (LKPD) is positive in improving students' mathematical communication skills because the model and media are combined to create a more interactive learning atmosphere and make students more active. In their research, Nurwijayanti & Sulisworo (2022) stated that using E-LKPD assisted by Liveworksheets based on Problem-Based Learning successfully improved students' mathematical communication skills. So, based on the background above, this study was conducted to determine the effect of the problem-based learning model assisted by interactive E-LKPD on students' mathematical communication skills.

Method

This research was conducted at SMP Negeri 5 Bandar Lampung in the odd semester of the 2024/2025 school year. The population in this study was all VIII grade students of SMP Negeri 5 Bandar Lampung, as many as 281 students distributed in nine classes, namely classes VIII.1 to VIII.9, and there were no superior classes. Sampling was done using the cluster random sampling technique. The selection of classes was determined randomly, and then two classes were selected as research samples, namely, class VIII.5, an experimental class of 30 students, and class VIII.7, a control class of 32 students.

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This research is quasi-experimental, consisting of independent variables, namely the problem-based learning model assisted by interactive E-LKPD, and the dependent variable, namely students' mathematical communication skills. The research design used was a randomized pretest-posttest control group design.

The procedure in this study consists of three stages: preparation, implementation, and final. The data in this study are quantitative in the form of initial data on mathematical communication skills obtained through pretest scores, final data on mathematical communication skills obtained through posttest scores, and data on score improvement (gain) in experimental and control classes.

The data collection technique used in this research is the test technique. The test technique was used to collect data on students' mathematical communication skills through a pretest and posttest. The test instrument described the SPLDV material, consisting of three questions that were the same between pretest and posttest in both classes. The preparation of test questions is adjusted to the indicators of mathematical communication skills, namely written text, drawing, and mathematical expression (Madhavia et al., 2020).

The validity of the instrument in this study was based on content validity through an assessment of the suitability of the test content with the test grid, and the suitability of the language used in the test with the students' language skills, carried out with a checklist (✓) by the partner teacher. The results of content validity showed that the test instrument had met the content validity.

The test results of the test instrument indicate that the test results of validity, reliability, distinguishing power and difficulty level meet the criteria. Hence, the test instrument in this study is suitable for use. The following is a recapitulation of the test results of the test instrument presented in Table 1.

Table 1. Recapitulation of Test Instrument Test Results

No	Validity	Reliability	Distinguishing Power		Level of Difficulty		Conclusion
1	Valid	0,76 (Reliable)	0,41	Good	0,38	Moderate	Worth Using
2			0,25	Enough	0,37	Moderate	Worth Using
3			0,28	Enough	0,33	Moderate	Worth Using

Before testing the hypothesis, a prerequisite test was first carried out, namely the normality test. The normality test that will be used in this study is the Chi-square test with $\alpha = 0.05$, with the following data:

Table 2. Normality Test Results of Students' Mathematical Communication Ability Improvement (gain) Score

Kelas	χ^2_{hitung}	χ^2_{tabel}	Keputusan Uji
Eksperimen	28,58	7,81	H_0 ditolak
Kontrol	6,89		H_0 diterima

Based on the normality test results, it can be concluded that the experimental class comes from an abnormally distributed population. In contrast, the control class comes from a normally distributed population. So, non-parametric tests are used for hypothesis testing. The non-parametric test used in this study is the Mann-Whitney U test.

Results and Discussion

Based on the pretest and posttest results, students' mathematical communication skills can be seen in Table 3.

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Table 3. Recapitulation of Mathematical Communication Ability Scores of Initial and Final Students

Class	Initial Score of Students' Mathematical Communication Ability				Final Score of Students' Mathematical Communication Ability			
	$\bar{x}$	**Lowest Score**	**Highest Score**	s	$\bar{x}$	**Lowest Score**	**Highest Score**	s
Experiments	10,23	5	16	2,62	37,23	27	45	5,70
control	8,94	2	20	4,53	26,28	18	38	3,81

Table 3 shows the differences in students' mathematical communication skills and their improvement from both classes. It can be seen that the provision of treatment with different learning methods in both classes affects the final score of students' mathematical communication skills. The average final score of students' mathematical communication ability in the class with the Problem-Based Learning model assisted by interactive E-LKPD is higher than that of students' mathematical communication ability with conventional learning.

The score of improvement (gain) of students' mathematical communication ability obtained from the gain index based on the pretest and posttest scores of students' mathematical communication ability in the experimental and control classes can be seen in Table 4.

Table 4. Students' Mathematical Communication Ability Gain Score

Class	Many Students	Average	Lowest Score	Highest Score	Standard Deviation
Experiments	30	0,72	0,45	0,91	0,15
control	32	0,44	0,21	0,70	0,11

Table 4 shows that the average score of improvement (gain) of students' mathematical communication skills in the experimental class is higher than that of the control class, with a difference of 0.28. In addition, the standard deviation for the improvement score (gain) of students' mathematical communication ability of the experimental class is higher than that of the control class, with a difference of 0.04. This shows that the distribution of students' mathematical communication skill gain scores in the experimental class with problem-based learning model assisted by interactive E-LKPD is more varied or heterogeneous than the control class with conventional learning.

After the prerequisite test, namely the normality test, it was found that the score of the increase (gain) of students' mathematical communication skills for the experimental class came from a population that was not normally distributed. In contrast, the control class came from a normally distributed population. Hypothesis testing of the students' mathematical communication skill gain scores used the Mann-Whitney U test. The hypothesis test results showed that the value of $|Z_{hitung}| = 5{,}94$ Furthermore, from the standard distribution list, Z is obtained. $Z_{table} = Z_{0{,}5-\frac{1}{2}\alpha} = Z_{0{,}5-0{,}025} = Z_{0{,}475} = 1{,}96$. Oleh karena itu $|Z_{count}| = 5{,}94 > Z_{table} = 1{,}96$ so H_0 is rejected. Thus, the median increase in mathematical communication skills of students who follow learning with a problem-based learning model assisted by interactive E-LKPD is higher than that of students who follow conventional learning. Thus, it can be concluded that the problem-based learning model assisted by interactive E-LKPD affects students' mathematical communication skills.

Furthermore, based on the initial and final students' mathematical communication ability scores, it is known that the increase in the achievement of mathematical communication ability indicators of students who take part in learning with problem-based learning models assisted by interactive and conventional E-LKPDs is presented in Table 5.

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Table 5. Achievement of Mathematical Communication Ability Indicators

Indicators	Experiment Class		Control Class	
	Initial	**Final**	**Initial**	Final
Written Text	24%	85%	14%	71%
Drawing	30%	71%	20%	40%
Mathematical Expression	19%	76%	21%	51%
Average	**25%**	**77%**	**18%**	**54%**

Based on Table 5. It can be seen that both classes experienced an increase in mathematical communication skills. The success of the problem-based learning model assisted by interactive E-LKPD can be seen from the achievement of students' mathematical communication ability indicators above. The analysis results show that the average increase in the percentage of indicator achievement in the problem-based learning model class assisted by interactive E-LKPD is 52%. In comparison, in the conventional class it is 36%.

The best indicator of improvement in the problem-based learning model class assisted by interactive E-LKPD is the written text indicator, by 61%. The lowest indicator of improvement in both classes is the drawing indicator in the problem-based learning model class, assisted by interactive E-LKPD by 41%, and while in the conventional class by 20%. This shows that the increase in the achievement of indicators of students' mathematical communication skills in the problem-based learning model class assisted by interactive E-LKPD for each indicator is higher than that of the conventional class. This study's results align with research conducted by Manurung *et al*. (2024), which states that the PBL model assisted by interactive LKS positively affects students' mathematical communication skills.

The factors that cause the problem-based learning model class assisted by interactive E-LKPD to increase higher than the conventional learning class on mathematical communication skills include applying the PBL model, which provides more opportunities for students to play an active role in the learning process. Learning begins with the presentation of problems that are relevant to everyday life through video shows or animations that are presented interactively in E-LKPD. This stage can encourage students to discuss in groups to analyze, formulate problems, and develop strategies systematically to solve problems. In addition, student worksheets act as a link in learning, increasing student activity and improving learning outcomes. This is supported by Grafillia's research (2023), which explains that PBL-based E-LKPD can be considered a good strategy in improving mathematical communication skills and critical thinking.

The use of interactive E-LKPD attracts students' interest and attention to learning materials. This is shown by students' enthusiasm when working on interactive E-LKPD to solve SPLDV by graphing. Based on observations, students seem more interested in the learning material because E-LKPD has interactive features such as coordinate grids, graphic simulations, line drawing media, and interactive tables. The features presented make it easier for students to visualize two lines on the coordinate plane and understand the intersection point as a solution to SPLDV. This aligns with the opinion of Diani *et al*. (2021), who say that interactive E-LKPD is designed with an attractive and practical appearance, and can increase innovation power and reduce the learning difficulties they face.

Learning stages with the PBL model assisted by interactive E-LKPD provide many opportunities for students to play an active role in the learning process through questions and answers, working together in groups, exchanging ideas or information to find the right solution, thus training students to think critically, logically, and systematically. This is in line with the opinion of Salsabilla *et al.* (2023) that the PBL model encourages students to collaborate in groups to solve problems, ask questions, participate in discussions, make logical arguments, and present thoughts systematically, so that it can help develop mathematical communication skills.

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In classes that follow learning with a problem-based learning model assisted by interactive E-LKPD, students are trained to actively discuss, dare to express their ideas or ideas, work together in groups, and exchange ideas and information, so that one group can understand the material studied better, so that students' mathematical communication skills can develop. This aligns with the research results of Nasri & Jamaan's (2022), which found that the PBL model assisted by interactive E-LKPD effectively develops mathematical communication skills.

In contrast, in classes with conventional learning, the learning process is still teacher-centered. Students tend to be passive, relying only on the teacher's explanation in front of the class, and lacking the awareness to learn independently. During the learning process in the conventional class, only a few students actively ask questions. In contrast, most others pay less attention and remain passive, even though they have been allowed to ask. When the teacher asked a question randomly and asked students to solve it, many refused because they did not understand how to solve it. This condition shows that students are not accustomed to communicating their ideas in front of the class, lack confidence in expressing opinions, and do not dare to try. As a result, students' critical thinking and mathematical communication skills are not optimally developed, which impacts the low achievement of students' mathematical communication skills in classes that follow conventional learning.

Conclusion

Based on the results of research and discussion, it is found that the improvement of mathematical communication skills of students who follow learning with a problem-based learning model assisted by interactive E-LKPD is higher than the improvement of mathematical communication skills of students who follow conventional learning. Thus, applying the problem-based learning model assisted by interactive E-LKPD affects students' mathematical communication skills.

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