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Enhancing Students' Mathematical Communication Skills through Reciprocal Teaching

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ABSTRACT

Mathematical communication is a key competence in mathematics learning because it enables students to express ideas, justify reasoning, and represent mathematical thinking clearly. This study examined the effect of Reciprocal Teaching on eighth-grade students' mathematical communication skills at SMP Negeri 1 Bangkinang. A quasi-experimental design with a nonequivalent control group was employed. The participants were divided into an experimental group taught through Reciprocal Teaching and a control group taught through conventional instruction. Data were collected using pretest and posttest measures of mathematical communication skills. The results showed that the experimental group obtained a higher posttest mean score (83.65) than the control group (72.67). The independent samples t-test indicated a significant difference between the two groups, $p < .001$. The N-gain score of the experimental group was high (0.73), whereas that of the control group was moderate (0.54). The effect size was also large (Cohen's $d = 1.528$), indicating that Reciprocal Teaching had a substantial effect on students' mathematical communication skills. These findings suggest that Reciprocal Teaching can be used as an instructional approach to support mathematical communication in junior secondary mathematics classrooms.

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Introduction

Mathematical communication skills are among the essential competencies in mathematics learning (Muzaini et al., 2023; Putri et al., 2022). These skills enable students to express mathematical ideas orally and in writing, use symbols, tables, diagrams, graphs, and other representations appropriately, and explain the reasoning behind the solution strategies they employ (Mentari & Syarifuddin, 2020). In mathematics learning, students' success should not be assessed solely by their ability to obtain correct final answers, but also by their ability to explain their thinking processes, interpret information, and communicate mathematical ideas clearly. The importance of mathematical communication is consistent with mathematics learning standards that position communication as one of the core processes in learning mathematics (OECD, 2018; Tohir, 2019; Zulkardi et al., 2020). The National Council of Teachers of Mathematics emphasizes that communication is an essential part of mathematics learning because it enables students to organize, clarify, and express their mathematical thinking (Lahdenperä et al., 2022). Thus, mathematical communication does not merely function as a means of presenting answers, but also as a process for constructing, testing, and deepening mathematical understanding.

However, students' mathematical communication skills remain a challenge in mathematics learning (Dreyfus, 2018; Gulkilik et al., 2020). Many students are able to follow examples of problem-solving procedures, but they experience difficulties when asked to explain their reasoning, represent ideas in different forms, read graphs, draw graphs, or connect mathematical information to problem contexts (Krawitz et al., 2026; Marufi et al., 2022; Nurwita et al., 2022). This condition indicates that mathematics learning has not fully encouraged students to express and justify their mathematical ideas.

This challenge is also reflected in Indonesian students' mathematics achievement in international assessments. The PISA 2022 results show that Indonesian students' mathematics scores remain below the OECD average (Qadry et al., 2022; Safrudiannur & Rott, 2019). These data should not be interpreted as a direct measure of mathematical communication skills, but they indicate that Indonesian students still face difficulties in using mathematics to reason, interpret, and solve problems in various contexts. These aspects are closely related to mathematical communication because students are required to understand information, explain ideas, use representations, and communicate mathematical reasoning effectively.

Similar problems were found at SMP Negeri 1 Bangkinang. Based on interviews with eighth-grade mathematics teachers, students still experienced difficulties in developing mathematical communication skills. Several problems were identified, including students' limited ability to read and draw graphs, difficulty solving problems that differed from given examples, a tendency to copy peers' work, and a lack of confidence in presenting their work in front of the class. These conditions indicate that students are not yet accustomed to communicating mathematical ideas, strategies, and reasoning independently.

One factor that may contribute to students' low mathematical communication skills is the persistence of teacher-centered instruction (Arifanti et al., 2024; Martínez et al., 2020). In this type of instruction, students mostly receive explanations, imitate examples, and complete routine exercises. They are rarely given opportunities to ask questions, clarify their understanding, explain their reasoning, engage in discussion, or compare solution strategies. In fact, mathematical communication develops through learning activities that provide students with opportunities to speak, write, interpret, and reflect on mathematical ideas.

Theoretically, mathematical communication skills are closely related to the view that learning mathematics is a social activity (Ayu et al., 2023; Kadir, 2008; Rachman & Rosnawati, 2021). Mathematical understanding is constructed not only through individual activity, but also through interaction, discussion, clarification, and negotiation of meaning with others. When students explain strategies, respond to questions, correct errors, and engage with peers' ideas, they do not merely communicate; they also strengthen the structure of their mathematical understanding. Therefore, mathematics learning should be designed to encourage students to actively express ideas and participate in mathematical dialogue.

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The Reciprocal Teaching model is relevant to this need. Reciprocal Teaching positions students as active participants in the learning process through four main strategies: summarizing, questioning, clarifying, and predicting (Kontorovich, 2017). The summarizing strategy trains students to restate mathematical information in a concise and structured manner (Hackenberg & Sevinc, 2022a). The questioning strategy encourages students to identify important information and test their understanding. The clarifying strategy helps students address conceptual or procedural ambiguities (Dominguez, 2019). The predicting strategy encourages students to use reasoning to anticipate the next solution steps or possible answers.

These four strategies are directly related to indicators of mathematical communication. Students are trained to understand information, express ideas, explain reasoning, use representations, and discuss mathematical thinking with others (Hackenberg & Sevinc, 2022a). Thus, Reciprocal Teaching not only encourages students to be active in learning, but also provides a structured approach for gradually developing their mathematical communication skills.

Previous studies have shown that Reciprocal Teaching can improve students' mathematical communication skills. However, empirical evidence regarding the effectiveness of this model still needs to be extended to different classroom contexts, learning topics, and student characteristics. In the context of SMP Negeri 1 Bangkinang, research is still needed to examine whether Reciprocal Teaching produces differences in students' mathematical communication skills compared with conventional instruction. In addition, the effectiveness of the model should be examined not only from students' final achievement, but also from their learning gains and the magnitude of the instructional effect. Based on the preceding discussion, this study aims to analyze the effectiveness of the Reciprocal Teaching model on the mathematical communication skills. Specifically, this study examines differences in mathematical communication skills between students taught through Reciprocal Teaching and those taught through conventional instruction, the improvement in students' mathematical communication skills after learning through Reciprocal Teaching, and the magnitude of the effect of Reciprocal Teaching on students' mathematical communication skills.

Method

Research Design

This study employed a quantitative approach using a quasi-experimental method. The research design was a nonequivalent control group design. This design was selected because the study was conducted in naturally existing classrooms; therefore, individual randomization into the experimental and control groups was not possible. The study involved two groups: an experimental group and a control group. The experimental group was taught using the Reciprocal Teaching model, whereas the control group was taught using conventional instruction. Before the treatment, both groups were administered a pretest to measure students' initial mathematical communication skills. After the instructional intervention was completed, both groups were administered a posttest to measure their mathematical communication skills after the treatment. The structure of the research design was as follows: the experimental group received a pretest, instruction using the Reciprocal Teaching model, and a posttest; meanwhile, the control group received a pretest, conventional instruction, and a posttest. The pretest was used to obtain information about students' initial abilities, whereas the posttest was used to identify changes in students' mathematical communication skills after instruction.

Participants

This study was conducted at SMP Negeri 1 Bangkinang during the second semester of the 2025/2026 academic year. The participants were eighth-grade students from two classes. One class was assigned as the experimental group, and the other class was assigned as the control group. The experimental group consisted of 23 students who received instruction using the Reciprocal Teaching model, whereas the control group consisted of 24 students who received conventional instruction. Thus, the total number of participants in this study was 46 students. The classes were selected based on the existing classroom structure at the school. Therefore, this study did not use individual randomization. To minimize the limitation of the nonequivalent control group design, pretest scores were used to examine the initial mathematical communication skills of students in both groups before the treatment was implemented.

Instruments

The main instrument used in this study was a mathematical communication skills test. The test was developed in the form of essay questions on data presentation topics. Essay questions were selected because they were considered appropriate for measuring students' ability to explain ideas, present information through representations, and use mathematical expressions in written form. The mathematical communication skills test was developed based on three indicators: written text, drawing, and mathematical expression. The written text indicator measured students' ability to provide mathematical explanations that were logical, clear, and conceptually appropriate. The drawing indicator measured students' ability to present mathematical ideas through pictures, tables, diagrams, or graphs. The mathematical expression indicator measured students' ability to translate mathematical situations into models or mathematical expressions and solve them correctly.

The test was scored using a rubric ranging from 0 to 4 for each indicator. A score of 0 was given when students provided no answer or when the answer did not demonstrate conceptual understanding. A score of 1 was given when only a small part of the answer was correct. A score of 2 was given when the answer demonstrated partial understanding but was incomplete or still contained errors. A score of 3 was given when the answer was mathematically correct but was not logically organized or still had weaknesses in presentation. A score of 4 was given when the answer was correct, complete, clear, and logically organized.

In addition to the test, this study used observation sheets. The observation sheets were used to record teacher and student activities during the learning process. In the experimental group, the observation focused on the implementation of the Reciprocal Teaching stages, namely summarizing, questioning, clarifying, and predicting. In the control group, the observation was used to record the implementation of conventional instruction. The observation data served as supporting data to ensure that the learning process was implemented according to the research design.

Before being used in the main study, the test instrument was piloted with 26 students. The pilot test was conducted to examine the validity, reliability, difficulty level, and discriminatory power of the test items. Item validity was analyzed using the Product Moment correlation with the assistance of SPSS version 22. The results showed that all six items had r-count values higher than the r-table value of 0.388 at the 0.05 significance level. The r-count values for the six items were 0.501, 0.435, 0.395, 0.529, 0.541, and 0.549. Therefore, all test items were considered valid for measuring students' mathematical communication skills.

Instrument reliability was analyzed using Cronbach's Alpha. The analysis produced a Cronbach's Alpha value of 0.497 for the six test items. This value indicates that the instrument

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had low to moderate reliability. Therefore, the interpretation of the test results should be made with caution. This reliability limitation was considered when interpreting the findings of the study. The item difficulty analysis showed that all six items were in the moderate category. The difficulty indices were 0.65, 0.60, 0.66, 0.58, 0.66, and 0.56. These results indicate that the items had an appropriate level of difficulty because they were neither too easy nor too difficult for students.

The discriminatory power analysis showed that one item was in the good category, three items were in the fair category, and two items were in the poor category. Item 5 had good discriminatory power; items 1, 4, and 6 had fair discriminatory power; and items 2 and 3 had poor discriminatory power. These results indicate that some items had limited ability to distinguish between students with high and low mathematical communication skills.

Data Collection

Data were collected through tests, observation, and documentation. The test served as the main technique for collecting data on students' mathematical communication skills. The test was administered twice, namely before and after the treatment. The pretest was administered to both the experimental and control groups before instruction began. The posttest was administered to both groups after all instructional activities had been completed. Observation was conducted during the learning process. The purpose of the observation was to record the implementation of instruction, teacher activities, and student activities. In the experimental group, observation was used to ensure that the learning process followed the stages of Reciprocal Teaching. In the control group, observation was used to ensure that instruction was implemented according to the conventional learning approach. Documentation was used as supporting data. The documentation included photographs of learning activities, student lists, instructional materials, and other documents relevant to the implementation of the study. The documentation data were not used to test the hypotheses but were used to support the description of the research implementation.

Data Analysis

The data were analyzed quantitatively using SPSS version 22. The data analysis consisted of several stages: descriptive analysis, assumption testing, difference testing, N-gain analysis, and effect size analysis. Descriptive analysis was used to describe the pretest and posttest scores of the experimental and control groups. The descriptive statistics reported included the number of students, minimum score, maximum score, mean, and standard deviation. This analysis provided an initial overview of students' mathematical communication skills before and after the treatment.

Assumption testing was conducted before hypothesis testing. The normality test was conducted using the Shapiro-Wilk test because the number of students in each group was relatively small. The data were considered normally distributed when the p-value was greater than 0.05. Homogeneity of variance was tested using Levene's test. The data were considered homogeneous when the p-value was greater than 0.05. Differences in mathematical communication skills between the experimental and control groups were analyzed using an independent samples t-test when the data met the assumptions of normality and homogeneity. This test was used to determine whether there was a significant difference between the learning outcomes of students in the experimental and control groups. If the data did not meet the normality assumption, the Mann-Whitney U test was used as a nonparametric alternative.

In addition to comparing posttest scores, this study also examined the equivalence of students' initial abilities based on pretest scores. This examination was important because the study used a nonequivalent control group design. If the pretest scores of the two groups did not differ significantly, the comparison of posttest scores could be used to evaluate the effectiveness of the treatment. If differences in initial ability were found, the interpretation of posttest results needed to consider the pretest scores. The improvement in students' mathematical communication skills was analyzed using normalized gain, or N-gain. N-gain was calculated by comparing the difference between posttest and pretest scores with the maximum possible score. The N-gain values were classified into three categories: high if the N-gain was greater than 0.70, moderate if the N-gain ranged from 0.30 to 0.70, and low if the N-gain was less than 0.30. The mean N-gain scores of the experimental and control groups were compared to determine differences in the improvement of mathematical communication skills between the two groups.

The magnitude of the effect of the Reciprocal Teaching model on students' mathematical communication skills was analyzed using effect size. The effect size was calculated using Cohen's d by comparing the mean difference between the experimental and control groups with the pooled standard deviation. Cohen's d was used to indicate the practical significance of the treatment. The interpretation of effect size followed general criteria: approximately 0.20 indicated a small effect, approximately 0.50 indicated a medium effect, and 0.80 or higher indicated a large effect. Thus, the analysis did not only show whether the difference between groups was statistically significant, but also indicated the practical magnitude of the effect of Reciprocal Teaching on students' mathematical communication skills.

Research Findings

Students' mathematical communication skills were analyzed based on pretest and posttest scores in the experimental and control groups. The experimental group was taught using the Reciprocal Teaching model, whereas the control group was taught using conventional instruction. The analysis included descriptive statistics, assumption testing, difference testing, N-gain analysis, and effect size analysis.

Descriptive Statistics

Table 1 presents the descriptive statistics of students' mathematical communication skills in the experimental and control groups.

Table 1. Descriptive Statistics of Students' Mathematical Communication Skills

Group	Test	N	Minimum	Maximum	Mean	SD
Experimental	Pretest	23	20	65	40.57	12.83
Experimental	Posttest	23	74	96	83.65	5.97
Control	Pretest	24	17	65	40.50	13.04
Control	Posttest	24	54	90	72.67	8.18

As shown in Table 1, the mean pretest score of the experimental group was 40.57, while that of the control group was 40.50. The very small difference between the two means indicates that the initial mathematical communication skills of students in both groups were relatively comparable. After the treatment, the mean posttest score of the experimental group increased to 83.65, whereas the mean posttest score of the control group increased to 72.67. These results indicate that both groups improved, but the improvement in the experimental group was greater than that in the control group.

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The distribution of scores also suggests a stronger improvement in the experimental group. The posttest standard deviation of the experimental group was 5.97, which was lower than that of the control group, 8.18. This indicates that students' posttest scores in the experimental group were more closely clustered around the mean than those in the control group.

Distribution of Mathematical Communication Skill Categories

Table 2 presents the distribution of students' mathematical communication skill categories.

Table 2. Distribution of Students' Mathematical Communication Skill Categories

Group	Test	Very Low	Low	Moderate	High	Very High
Experimental	Pretest	21 students (91.30%)	2 students (8.70%)	0	0	0
Experimental	Posttest	0	1 student (4.35%)	7 students (30.43%)	10 students (43.48%)	5 students (21.74%)
Control	Pretest	21 students (87.50%)	3 students (12.50%)	0	0	0
Control	Posttest	1 student (4.17%)	13 students (54.17%)	7 students (29.17%)	2 students (8.33%)	1 student (4.17%)

As shown in Table 2, before the treatment, most students in both groups were in the very low category. After the treatment, the distribution of the experimental group shifted to the moderate, high, and very high categories. In the experimental group, 43.48% of students were in the high category and 21.74% were in the very high category. In contrast, most students in the control group remained in the low category, accounting for 54.17%. This finding indicates that Reciprocal Teaching produced a stronger shift in students' mathematical communication skill categories than conventional instruction.

Normality Test

The Shapiro-Wilk test was used to examine data normality because the sample size in each group was fewer than 50. The results are presented in Table 3.

Table 3. Results of the Shapiro-Wilk Normality Test

Group	Test	Statistic	df	p
Control	Pretest	0.964	24	0.532
Control	Posttest	0.983	24	0.948
Experimental	Pretest	0.952	23	0.327
Experimental	Posttest	0.958	23	0.416

Table 3 shows that all p-values were greater than 0.05. Therefore, the pretest and posttest scores in both the experimental and control groups were normally distributed. These results indicate that the data met the normality assumption for parametric analysis.

Homogeneity Test

The homogeneity of variance was examined using Levene's test. The results are presented in Table 4.

Table 4. Results of Levene's Test for Homogeneity of Variance

Data	Levene Statistic	df1	df2	p
Pretest	0.009	1	45	0.926
Posttest	0.942	1	45	0.337

As shown in Table 4, the p-value for the pretest data was 0.926, and the p-value for the posttest data was 0.337. Both values were greater than 0.05. Therefore, the variances of the pretest and posttest scores in the experimental and control groups were homogeneous.

Equivalence of Initial Ability

The equivalence of students' initial ability was examined based on the pretest scores of the experimental and control groups. The mean pretest score of the experimental group was 40.57, while that of the control group was 40.50. The difference between the two means was only 0.07. Based on the independent samples t-test, there was no significant difference in initial mathematical communication skills between the experimental and control groups, $t(45) = 0.019$, $p = 0.985$. Therefore, the two groups can be considered relatively equivalent before the treatment was implemented.

Table 5. Equivalence Test of Initial Ability Based on Pretest Scores

Group	N	Mean	SD	t	df	p
Experimental	23	40.57	12.83	0.019	45	0.985
Control	24	40.50	13.04			

Posttest Difference Test

After the data met the assumptions of normality and homogeneity, the posttest scores of the experimental and control groups were compared using an independent samples t-test. The results are presented in Table 6.

Table 6. Results of the Independent Samples t-Test on Posttest Scores

Group	N	Mean	SD	t	df	p
Experimental	23	83.65	5.97	5.240	45	< .001
Control	24	72.67	8.18			

The independent samples t-test showed a significant difference between the posttest scores of the experimental and control groups, $t(45) = 5.240$, $p < .001$. The mean posttest score of the experimental group was higher than that of the control group. This result indicates that students taught using Reciprocal Teaching demonstrated better mathematical communication skills than students taught using conventional instruction.

N-Gain Analysis

N-gain analysis was conducted to examine the improvement in students' mathematical communication skills from pretest to posttest. The results are presented in Table 7.

Table 7. Results of N-Gain Analysis

Group	Mean N-Gain	Percentage	Category
Experimental	0.726	72.63%	High
Control	0.540	53.96%	Moderate

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As shown in Table 7, the experimental group obtained a mean N-gain of 0.726, or 72.63%, which falls into the high category. The control group obtained a mean N-gain of 0.540, or 53.96%, which falls into the moderate category. These results indicate that the improvement in students' mathematical communication skills was greater in the experimental group than in the control group.

Effect Size

Effect size was calculated using Cohen's d to determine the magnitude of the effect of Reciprocal Teaching on students' mathematical communication skills. The calculation was based on the posttest means and the pooled standard deviation of the experimental and control groups. The results are presented in Table 8.

Table 8. Effect Size Calculation

Experimental Mean	Control Mean	Pooled SD	Cohen's d	Interpretation
83.65	72.67	7.184	1.528	Large effect

As shown in Table 8, Cohen's d was 1.528. This value indicates that the Reciprocal Teaching model had a large effect on students' mathematical communication skills. Therefore, the difference between the experimental and control groups was not only statistically significant but also practically meaningful.

The findings show that the experimental and control groups had relatively equivalent initial mathematical communication skills before the treatment. After instruction, the experimental group achieved a higher mean posttest score than the control group. The independent samples t-test showed a significant difference between the two groups, $p < .001$. The N-gain analysis indicated that the improvement in the experimental group was in the high category, whereas the improvement in the control group was in the moderate category. In addition, Cohen's d of 1.528 indicated that Reciprocal Teaching had a large effect on students' mathematical communication skills. Overall, these findings suggest that Reciprocal Teaching is effective in improving students' mathematical communication skills compared with conventional instruction.

Discussion

The findings of this study indicate that Reciprocal Teaching had a positive effect on students' mathematical communication skills. The experimental and control groups had relatively similar initial abilities, as shown by the close pretest mean scores. However, after the intervention, the experimental group achieved a higher posttest mean score than the control group. This difference suggests that the improvement in students' mathematical communication skills was not merely caused by natural learning progression, but was closely related to the instructional treatment implemented in the experimental class (Kontorovich, 2017). The significant difference between the experimental and control groups supports the claim that Reciprocal Teaching is more effective than conventional instruction in improving students' mathematical communication skills (Dominguez, 2019; Hackenberg & Sevinc, 2022b). The independent samples t-test showed a statistically significant difference in posttest scores, with the experimental group outperforming the control group. This result is important because mathematical communication requires more than procedural fluency. Students need opportunities to explain ideas, interpret information, use representations, justify reasoning, and respond to others' thinking (Kadir, 2008). Reciprocal Teaching provides such opportunities through structured learning activities. The higher N-Gain score in the experimental group strengthens this interpretation. The experimental group reached a high N-Gain category, whereas the control group reached a moderate category. This means that students taught through Reciprocal Teaching did not only achieve higher final scores, but also demonstrated greater improvement from their initial ability. The difference in N-Gain indicates that Reciprocal Teaching helped students move from limited initial communication ability toward stronger mathematical expression, representation, and explanation.

This improvement can be explained by the characteristics of Reciprocal Teaching. The model involves four main strategies: summarizing, questioning, clarifying, and predicting. These strategies are closely aligned with the components of mathematical communication. Summarizing encourages students to restate mathematical information in their own words. Questioning trains students to identify important ideas and examine their understanding (Ayu et al., 2023; Rachman & Rosnawati, 2021). Clarifying helps students address conceptual or procedural confusion. Predicting encourages students to use reasoning to anticipate possible solution steps. Through these activities, students are not positioned as passive recipients of information, but as active participants who construct and communicate mathematical meaning. The findings also suggest that communication in mathematics develops more effectively when students are involved in social interaction. In conventional instruction, students often listen to explanations, imitate examples, and complete routine exercises. Such activities may help students follow procedures, but they do not always train students to express mathematical reasoning clearly. In contrast, Reciprocal Teaching creates learning situations in which students must explain, ask, clarify, and discuss mathematical ideas (Freeman et al., 2020; Muzaini et al., 2023; Putri et al., 2022). These processes help students organize their thinking and make their mathematical understanding visible.

The large effect size provides further evidence of the practical significance of the intervention. Cohen's d of 1.528 indicates that the difference between the experimental and control groups was not only statistically significant, but also educationally meaningful. This finding is important because statistical significance alone does not always show the practical value of an instructional model. In this study, the large effect size indicates that Reciprocal Teaching had a substantial impact on students' mathematical communication skills. The shift in students' achievement categories also supports the effectiveness of the model. Before the intervention, most students in both groups were in the very low category. After the intervention, many students in the experimental group moved into the moderate, high, and very high categories. In contrast, most students in the control group remained in the low category. This pattern shows that Reciprocal Teaching did not only improve the average score, but also changed the distribution of students' mathematical communication performance.

These findings are consistent with previous studies reporting that Reciprocal Teaching can improve students' mathematical communication skills. However, this study adds evidence from the context of eighth-grade students learning statistics at SMP Negeri 1 Bangkinang. The results show that Reciprocal Teaching is relevant not only for reading comprehension or general classroom discussion, but also for mathematics learning that requires students to interpret data, represent information, explain procedures, and communicate mathematical ideas (Charalambous et al., 2020; Martínez et al., 2020). Theoretically, this study supports the view that mathematical communication is developed through active, reflective, and dialogic learning. Students' ability to communicate mathematics improves when they are given structured opportunities to process information, formulate questions, clarify meaning, and explain their reasoning. Therefore, Reciprocal Teaching can be viewed as an instructional model that connects cognitive activity and social interaction in mathematics learning.

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Practically, the findings imply that mathematics teachers need to provide learning activities that go beyond giving explanations and assigning routine exercises. Teachers can use Reciprocal Teaching to guide students in reading mathematical information, asking relevant questions, clarifying unclear concepts, predicting solution strategies, and presenting mathematical reasoning (Güven Akdeniz & Argün, 2021; Huang et al., 2021; Kang & Liu, 2018). These activities can help students become more confident and more precise in communicating mathematical ideas. However, the findings should be interpreted with several considerations. First, this study used a quasi-experimental design, so the classes were not formed through individual randomization. Although the pretest results showed relatively similar initial abilities, other classroom factors may still have influenced the results. Second, the study involved only two classes in one school, so the findings cannot be generalized broadly without further research in different schools, grade levels, and mathematical topics. Third, the reliability of the test instrument should be strengthened in future studies to ensure more stable measurement of students' mathematical communication skills.

Overall, the findings indicate that Reciprocal Teaching is an effective instructional model for improving students' mathematical communication skills. The model supports students in expressing ideas, using mathematical representations, clarifying understanding, and explaining reasoning. The significant posttest difference, higher N-Gain score, and large effect size provide consistent evidence that Reciprocal Teaching offers stronger support for mathematical communication than conventional instruction.

Conclusion

The findings indicate that the Reciprocal Teaching model was effective in improving students' mathematical communication skills. Students who learned through Reciprocal Teaching demonstrated better performance than those who received conventional instruction. The improvement was reflected in their ability to express mathematical ideas, use representations, explain reasoning, and communicate solution strategies more clearly. These findings suggest that Reciprocal Teaching can be used as an instructional alternative to support mathematical communication in junior secondary mathematics classrooms. The learning activities embedded in Reciprocal Teaching, namely summarizing, questioning, clarifying, and predicting, provide students with structured opportunities to engage actively with mathematical ideas and communicate their thinking. However, this conclusion should be interpreted within the context of a quasi-experimental study involving two classes in one school. Future studies may involve larger samples, different mathematical topics, and instruments with stronger reliability to provide broader evidence regarding the effectiveness of Reciprocal Teaching in mathematics learning.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

J. conceived the research idea presented and collected the data. The other two authors (Z. and A.) actively participated in the development of the theory, methodology, organization and analysis of the data, discussion of the results, and final approval of the work. All authors declare that the final version of this paper has been read and approved. The total percentage of contributions to the conceptualization, preparation, and correction of this paper is as follows: J.: 60%, Z.: 20%, and A.: 20%.

Data Availability Statement

The authors declare that the data supporting the findings of this study are available from the corresponding author (J.) upon reasonable request.

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