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Reciprocal Teaching as a Participatory Teaching Method to Improve Mathematical Reasoning and Self-Confidence in Middle School Students

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ABSTRACT
This study investigates the effect of the Reciprocal Teaching (RT) model, implemented as a Participatory Teaching Method, on Grade VII middle school students' mathematical reasoning ability and self-confidence. A quasi-experimental one-group pretest-posttest design was employed with 32 students from SMP Negeri 6 Yogyakarta, selected through purposive sampling. The intervention consisted of four structured instructional sessions on quadrilateral and triangle geometry, incorporating the four RT strategies: predicting, questioning, clarifying, and summarizing. Data were collected using expert-validated instruments: a mathematical reasoning essay test and a Likert-scale self-confidence questionnaire, with reliability confirmed via Cronbach's alpha. Results showed statistically significant improvements in mathematical reasoning (M = 51.43 to 71.78) and self-confidence (M = 35.40 to 39.50), both indicating large effect sizes. Analysis by reasoning indicator revealed gains across conjecture-making, logical argumentation, and conclusion drawing. These findings suggest that RT effectively enhances both cognitive and affective dimensions of mathematics learning. Practical implications for mathematics educators and directions for future research are discussed.

KEYWORDS: Participatory Teaching Method; Reciprocal Teaching; Mathematical Reasoning; Self-Confidence, Effect Size

I. INTRODUCTION

Mathematics plays a crucial role in developing logical, critical, and reflective thinking skills needed to address real-world problems. In learning, mathematics is not only aimed at mastering formulas and procedures but also at enabling students to reason and gain confidence in using mathematics meaningfully (Mierluş-Mazilu & Yilmaz, 2024). As part of STEM education, mathematics supports students in reasoning and solving problems systematically (Anderson & Makar, 2024). Moreover, the integration of technology and contextual learning approaches facilitates concept comprehension, helps students relate mathematics to daily life, and promotes the development of mathematical literacy and reasoning skills (Hajizah et al., 2021; S. Rohman et al., 2019).

However, in practice, Indonesian students' mathematical reasoning abilities remain relatively low, as evidenced by TIMSS and PISA results, which indicate weaknesses in mathematical thinking and reasoning (Hadi et al., 2018; Lailiyah et al., 2018). This underperformance is not only attributed to limited exposure to reasoning-based tasks and less effective instructional approaches (Johar et al., 2018), but also to affective factors such as self-confidence, which significantly influence student performance. Students with higher self-confidence tend to reason and solve problems more effectively, whereas low self-confidence and mathematics anxiety can hinder engagement and understanding (Fahmi et al., 2021; Kunhertanti & Santosa, 2018).

Within this framework, there is a growing need for more participatory and dialogic teaching strategies that position students as active agents in the learning process (Bieber et al., 2009; Sayadi & Pangandaman, 2025). Reciprocal Teaching (RT) aligns well with this approach, as it emphasizes collaboration, reflective communication, and shared responsibility between teachers and students in constructing understanding (Ferrer et al., 2011; Tarchi & Pinto, 2016). Through its four core strategies—predicting, questioning, clarifying, and summarizing—RT fosters conversation and reflection-based learning that enhances active participation, critical thinking, and meaningful peer interaction (Mafarja, Mohamad, et al., 2023; Mulbar et al., 2019).

Previous studies have demonstrated the effectiveness of RT in improving conceptual understanding, critical thinking, and students' self-confidence (Maulani et al., 2017; Prasetio et al., 2018; Ulfiyati et al., 2025). In the context of mathematics education, this dialogic and collaborative approach is particularly relevant for developing mathematical reasoning, as it allows students to explain, defend, and revise their ideas openly (Qohar & Sumarmo, 2013). Additionally, the social engagement inherent in RT supports the development of self-confidence and learning motivation (Machi & Nakaya, 2014; Setiawan et al., 2022).

Despite these promising findings, empirical studies that simultaneously examine RT's effect on both mathematical reasoning and self-confidence in the Indonesian junior high school context, while reporting effect sizes and indicator-level analyses, remain limited. Addressing this gap, the present study aims to: (1) examine whether RT significantly improves students' mathematical reasoning ability; (2) determine whether RT significantly enhances students' self-confidence; and (3) analyze the practical magnitude of these effects through Cohen's d estimation and reasoning indicator analysis.

II. THEORETICAL FRAMEWORK

A. Reciprocal Teaching as a Participatory Teaching Method

The Participatory Teaching Method emphasizes the active engagement of learners in the learning process through collaboration, reflection, and practical application. This approach is rooted in the constructivist theories of Piaget and Vygotsky, which highlight the importance of cognitive conflict and social interaction in the construction of knowledge (Ferrante, 2018). Through participatory learning, students do not merely receive information passively but actively construct understanding through discussion and collaborative activities. Consequently, participatory teaching methods promote meaningful, critical, and socially oriented learning experiences that foster deeper comprehension and transformative thinking (Araya-Crisóstomo & Urrutia, 2022; Calderón, 2004).

In this context, Reciprocal Teaching (RT), developed by Palincsar and Brown based on Vygotsky’s social constructivist theory (Pratiwi et al., 2023), can be regarded as a form of participatory teaching method. This model emphasizes the importance of social interaction and dialogue in building shared understanding among students. In practice, students take turns acting as both instructor and participant within small groups, creating a participatory and dialogic learning process. The dialogic interaction characteristic of RT positions it within participatory teaching methods, as learning occurs through active participation, negotiation of meaning, and collective reflection (Mulbar et al., 2019; Tarchi & Pinto, 2016).

RT employs four core strategies (predicting, questioning, clarifying, and summarizing) to facilitate deep understanding and foster higher-order thinking skills. Through predicting, students learn to anticipate content and activate prior knowledge; questioning develops their critical inquiry skills; clarifying helps them resolve misunderstandings through peer dialogue; and summarizing encourages students to synthesize the main ideas of the lesson. These strategies have been shown to effectively enhance conceptual understanding, critical thinking, and peer-to-peer communication (Azizah et al., 2020; Rohman, 2019). Together, they create a recursive cycle of metacognitive engagement that characterizes RT as a genuinely participatory learning experience.

B. Mathematical Reasoning

The theory of mathematical reasoning emphasizes that reasoning is a crucial component of mathematics learning, as it involves deriving statements from given problems and constructing arguments to justify conclusions (Rohati et al., 2023). There are two main types of mathematical reasoning: imitative reasoning, which focuses on applying familiar procedures, and creative reasoning, which requires students to generate new strategies and solutions (Rokhima et al., 2019). Creative reasoning is considered essential because it contributes to deeper conceptual understanding, and research has shown a positive relationship between mathematical understanding and reasoning ability. Teachers should therefore encourage students to develop creative reasoning through open-ended problem-solving activities and tasks with multiple solutions to strengthen logical thinking and mathematical comprehension.

In the Indonesian curriculum framework, mathematical reasoning is operationalized through three key indicators: (1) making conjectures, formulating hypotheses based on observed mathematical patterns; (2) providing logical arguments, constructing coherent justifications for mathematical claims; and (3) drawing conclusions, deriving valid inferences from given premises (Rohati et al., 2023; Lailiyah et al., 2018). The dialogic structure of RT, in which students are routinely required to articulate, defend, and evaluate mathematical ideas, directly aligns with these indicators and provides the theoretical rationale for examining RT's effect on mathematical reasoning.

C. Self-Confidence

Self-confidence in mathematics refers to students’ belief in their ability to understand and solve mathematical problems, which plays a critical role in fostering active participation and academic achievement (Kunhertanti & Santosa, 2018). According to self-efficacy theory, an individual’s belief in their capability to execute tasks influences engagement and learning success, such that students with higher self-confidence tend to perform better in mathematics (Ferdianto et al., 2023).

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Research indicates a bidirectional relationship between self-confidence and mathematics achievement: students with higher self-confidence engage more actively and perform better, while success experiences reinforce confidence over time (Fahmi et al., 2021). The collaborative and socially supportive environment of RT may foster self-confidence by providing structured, lower-stakes peer interaction as an alternative to potentially anxiety-inducing whole-class settings (Machi & Nakaya, 2014; Setiawan et al., 2022). For students with initially low confidence, the scaffolded group dialogue characteristic of RT offers incremental success experiences that may gradually build mathematical self-efficacy.

III. RESEARCH METHOD

A. Research Design and Participants

This study employed a quantitative research approach with a quasi-experimental one-group pretest-posttest design to investigate the effect of the Reciprocal Teaching model on students' mathematical reasoning ability and self-confidence. This design was selected to examine changes in students' abilities before and after the intervention within a naturalistic classroom setting, where random assignment to a control group was not feasible. While the absence of a control group limits causal inference, the use of validated instruments, standardized intervention protocols, and effect size reporting strengthens the interpretive value of the findings.

The research was conducted at SMP Negeri 6 Yogyakarta during the second semester of the academic year. The instructional intervention focused on quadrilateral and triangle geometry, which are core topics in the Grade VII mathematics curriculum. The learning activities were implemented over four instructional sessions, each lasting 80-100 minutes, designed according to the four stages of Reciprocal Teaching, predicting, questioning, clarifying, and summarizing, to actively engage students in constructing mathematical understanding and reasoning.

The research sample consisted of 32 students from class VII C, selected through purposive sampling based on considerations of class characteristics and learning conditions. All students in the selected class participated in the study. Institutional approval was obtained prior to data collection, and informed consent was secured from participants and guardians.

B. Intervention

The RT intervention was implemented by the classroom mathematics teacher, who received structured training on RT procedures prior to the study. Each session followed a standardized instructional module aligned with the four RT strategies. In the predicting phase, students examined problem stems and formulated hypotheses about solution approaches. In the questioning phase, student-generated mathematical questions were shared and evaluated within small groups of four to five students. The clarifying phase involved structured peer explanation of challenging concepts, while the summarizing phase required each group to articulate and present the key mathematical principles from the session.

An independent observer monitored all four sessions using structured observation sheets to document RT strategy fidelity, student participation, and teacher facilitation behaviors. Classroom activities were highly engaged, with an average participation rate of 98% for both teachers and students, indicating strong procedural fidelity throughout the intervention.

C. Instruments

Data were collected using several instruments. Mathematical reasoning ability was measured using essay-type tests administered as a pretest and posttest, designed to assess students' abilities in making conjectures, providing logical arguments, and drawing conclusions related to geometric concepts. Each test comprised items assessing these three reasoning indicators through tasks requiring genuine argumentation rather than procedural recall. Students' self-confidence was measured using a self-confidence questionnaire based on a Likert scale, covering indicators such as confidence in expressing ideas, persistence in solving problems, and belief in one's own mathematical abilities. In addition, observation sheets were used to document students' engagement and learning behaviors during RT implementation.

All instruments were subjected to expert validation to ensure content validity and clarity, with revisions made based on expert feedback prior to administration. Validation was conducted using Aiken's V index, yielding values of 0.854 for the pretest, 0.844 for the posttest, and 0.800 for the self-confidence questionnaire, all exceeding the recommended threshold of 0.75. Instrument reliability was assessed via Cronbach's alpha, yielding values of 0.82 for the reasoning tests and 0.79 for the self-confidence questionnaire, indicating acceptable internal consistency.

D. Data Analysis

The collected data were analyzed using descriptive statistics to describe students' mathematical reasoning and self-confidence levels before and after the intervention.

Normality of score distributions was examined using the Shapiro-Wilk method, which confirmed normality for all variables ($p > .05$), satisfying the parametric assumption for paired-sample t-test analysis. Paired-sample t-tests were then conducted to determine whether significant differences existed between pretest and posttest scores, with the significance level set at $\alpha = 0.05$.

Critically, effect size was calculated using Cohen's d to provide an estimate of practical significance independent of sample size. Cohen's d values were interpreted according to conventional benchmarks: small (d = 0.20), medium (d = 0.50), and large ($d \geq 0.80$). Additionally, 95% confidence intervals for effect size estimates were computed, and scores were analyzed separately by reasoning indicator to identify differential gains and their alignment with specific RT strategies.

IV. RESULTS

A. Descriptive Statistics and Paired t-Test Results

The study was conducted with 32 students from class VII C, who participated in four mathematics sessions with an observer present throughout. Reciprocal Teaching was applied consistently according to the instructional module. Table 1 presents the descriptive and inferential statistics for mathematical reasoning ability and self-confidence.

Table 1. Descriptive Statistics, Paired t-Test Results, and Effect Sizes

Variable	Pre test M (SD)	Post test M (SD)	Gain	t(31)	p
Mathematical Reasoning	51.43 (18.47)	71.78 (16.56)	+20.35	-8.455	< .001
Self-Confidence	35.40 (4.21)	39.50 (3.87)	+4.10	-7.200	< .001

Note. *SD values in parentheses. df = 31 for all analyses. p-values reflect two-tailed tests.*

Prior to the intervention, students completed a pretest to assess initial mathematical reasoning and a self-confidence questionnaire to map their confidence levels. Pretest results indicated a mean mathematical reasoning score of 51.43 (SD = 18.47), with only five students (15.6%) meeting the Minimum Mastery Criteria (MMC) of 78. Following four sessions of Reciprocal Teaching, posttest results showed a notable improvement in mathematical reasoning, with a mean score of 71.78 (SD = 16.56). The reduced standard deviation at posttest suggests a convergence of performance levels, indicating that lower-performing students demonstrated proportionally greater gains. The paired t-test yielded a statistically significant result, $t(31) = -8.455$, $p < .001$.

Self-confidence scores also increased from a pre-intervention mean of 35.40 to 39.50 post-intervention, with reduced standard deviation, indicating a more evenly distributed confidence level among students. The paired t-test for self-confidence was similarly significant, $t(31) = -7.200$, $p < .001$. Following the intervention, fourteen students (43.8%) met the MMC for mathematical reasoning, compared to five (15.6%) prior to the intervention. These p-values, well below .05, indicate significant differences between pretest and posttest scores, thus rejecting the null hypothesis for both variables.

B. Effect Size Analysis

To supplement statistical significance testing and evaluate the practical magnitude of observed improvements, Cohen's d was calculated for both outcome variables (Table 2).

Table 2. Effect Size (Cohen's d) and 95% Confidence Intervals

Variable	Cohen's d	Magnitude	95% CI	Interpretation
Mathematical Reasoning	1.49	Large	[1.01, 1.97]	Practically significant
Self-Confidence	1.01	Large	[0.58, 1.44]	Practically significant

Note. *CI = Confidence Interval. Effect size benchmarks: small = 0.20, medium = 0.50, large ≥ 0.80*

Both variables demonstrated large effect sizes: Cohen's d = 1.49 for mathematical reasoning and d = 1.01 for self-confidence. The 95% confidence intervals for both estimates exclude zero and fall well above medium effect size boundaries, providing robust evidence for the practical significance of the observed improvements. These findings indicate that the RT intervention produced not only statistically reliable but also substantively meaningful gains in both cognitive and affective dimensions of mathematics learning.

C. Analysis by Reasoning Indicator

To provide a more nuanced understanding of reasoning development, pretest and posttest scores were analyzed separately for each of the three target reasoning indicators (Table 3).

Table 3. Pre-Post Comparison by Mathematical Reasoning Indicator

Reasoning Indicator	Pre test	Post test	Gain	Aligned RT Strategy

	M	M		
Making Conjectures	48.2	69.4	+21.2	Predicting, Questioning
Logical Argumentation	52.1	73.6	+21.5	Clarifying, Questioning
Drawing Conclusions	53.9	72.3	+18.4	Summarizing

Note. *Scores are reported as percentage of maximum possible score per indicator. RT = Reciprocal Teaching.*

Gains were observed across all three reasoning indicators, with logical argumentation demonstrating the largest improvement (+21.5 points), followed by conjecture-making (+21.2 points) and conclusion drawing (+18.4 points). These patterns align theoretically with the RT strategies most directly targeting each indicator: the predicting and questioning phases most directly engage conjecture-making and argumentation, while summarizing most directly targets conclusion drawing. The somewhat smaller gain in conclusion drawing may reflect the greater cognitive complexity required to synthesize full reasoning chains.

V. DISCUSSION

The findings of this study indicate that the implementation of the Reciprocal Teaching model significantly enhances students' mathematical reasoning and self-confidence, consistent with previous research on the effectiveness of participatory learning methods. Reciprocal Teaching, as a collaborative strategy involving teacher-student and peer-to-peer dialogue through predicting, questioning, clarifying, summarizing, and feedback (Mafarja, Zulnaidi, et al., 2023), helps students gain a deeper understanding of mathematical problems, thereby improving their critical thinking and reasoning skills (Aslam et al., 2021). Moreover, this method promotes the development of students' mathematical communication, which is essential for problem-solving and constructing more complex mathematical concepts (Qohar & Sumarmo, 2013).

The improvement in mathematical reasoning can be understood through the mechanism of externalized mathematical thinking. The RT framework requires students to articulate their reasoning processes across four iterative phases, creating sustained opportunities to formalize, evaluate, and refine mathematical arguments. This process aligns with theoretical accounts of how dialogic instruction promotes the transition from imitative to creative reasoning (Rokhima et al., 2019; Rohati et al., 2023). The indicator-level analysis reveals broadly distributed gains across all three reasoning dimensions, suggesting that RT's four-strategy cycle engaged the full reasoning construct rather than narrowly targeting a single competency.

The gain in logical argumentation was particularly notable. The clarifying strategy directly engages the argumentation indicator by requiring students to construct coherent, audience-directed justifications for their mathematical reasoning. This mechanism parallels the learning-by-teaching literature, which demonstrates that the act of explanation benefits the explainer's understanding by identifying gaps and strengthening conceptual connections (Qohar & Sumarmo, 2013; Aslam et al., 2021). The somewhat smaller gain in conclusion drawing suggests that future RT implementations might benefit from more explicit attention to the summarizing strategy to strengthen this dimension.

In addition to reasoning, Reciprocal Teaching also contributed to increasing students' self-confidence. These findings align with previous research. Improved comprehension and active engagement in group learning strengthen students' academic self-concept, a key component of self-confidence (Machi & Nakaya, 2014). Participation in discussions, providing feedback, and learning from peers offer collaborative experiences that enhance self-efficacy, particularly for students with initially low confidence. Furthermore, this strategy fosters mathematical persistence, enabling students to face academic challenges more confidently and engage actively in problem-solving (Setiawan et al., 2022). The reduction in standard deviation for self-confidence scores at posttest indicates that the intervention was particularly beneficial for students who initially demonstrated lower confidence, consistent with RT's scaffolded structure that provides proportionally more support to those who need it most.

Although this study was limited to a single class, the quadrilateral and triangle topics, and a short intervention duration, the results—bolstered by large effect sizes and indicator-level analysis—demonstrate that Reciprocal Teaching effectively improves both mathematical reasoning and self-confidence. The model fosters a collaborative learning environment that supports critical thinking and problem-solving, making it a viable and evidence-based alternative strategy in mathematics instruction. Future research employing control group designs, larger and more diverse samples across multiple schools, extended intervention durations, and mediation analyses would strengthen the validity and generalizability of these findings.

VI. CONCLUSION

Based on the study conducted at SMP Negeri 6 Yogyakarta, the implementation of the Reciprocal Teaching model was shown to significantly enhance students' mathematical reasoning and self-confidence through active engagement, collaborative discussions, and meaningful social interactions among learners. Large effect sizes for both outcomes confirm that improvements were not only statistically significant but also practically meaningful. Analysis by reasoning indicator revealed distributed gains across conjecture-making, logical argumentation, and conclusion drawing, with the largest improvements associated with RT strategies most directly targeting each indicator.

This model promotes critical thinking, problem-solving, and confidence-building, while providing a more interactive and participatory learning experience. For practitioners, RT can be implemented within existing classroom structures without extensive resource requirements, making it practically accessible for Indonesian school contexts. Teachers are encouraged to invest in explicit modeling of each RT strategy and to provide structured reflection opportunities to maximize reasoning and confidence benefits. It is recommended that further research explore RT's application across different contexts, grade levels, and longer intervention durations to maximize improvements in students' reasoning skills and self-confidence, and to establish a stronger causal evidence base for participatory mathematics instruction.

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