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Transforming Mathematical Communication: The Effectiveness of RADEC Learning Model in Elementary Education

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Abstract
Mathematical communication skills represent fundamental competencies essential for mathematical literacy development, yet elementary students frequently demonstrate passive engagement in mathematical discourse due to traditional instructional approaches that limit collaborative interaction and communication skill development. This quasi-experimental study employed a pretest-posttest non-equivalent control group design to investigate the effectiveness of the RADEC (Read, Answer, Discuss, Explain, Create) learning model in enhancing mathematical communication skills among elementary students. Participants comprised 51 third-grade students from SD Negeri Gendongan 01 Salatiga, with 27 students in the experimental group receiving RADEC instruction and 24 students in the control group receiving conventional mathematics instruction. Data were collected through validated essay-based assessments measuring written text, drawing, and mathematical expression competencies, supplemented by observations and interviews. Statistical analysis employed Independent Sample T-Tests using SPSS version 27. The experimental group achieved significantly superior performance with a mean score of 80.56 compared to the control group's mean score of 63.83 ($p = 0.015$, $t = -2.534$). Performance distribution analysis revealed 63% of experimental students attained very high achievement levels versus 50% in the control group, while low-performing students decreased from 13% to 4% following RADEC implementation. The RADEC model's systematic progression through Read, Answer, Discuss, Explain, and Create phases effectively develops mathematical communication competencies by facilitating active engagement with mathematical language, collaborative discourse, and creative representation generation. These findings support theoretical frameworks emphasizing mathematical communication as a fundamental process skill essential for mathematical literacy development and provide empirical evidence for student-centered pedagogical approaches in elementary mathematics education.

INTRODUCTION

Mathematics, characterized as an abstract logical science, often presents significant challenges for students in developing comprehensive understanding and effective communication skills (Anggraini, 2021). The communicative perspective in mathematics education has gradually gained importance over the past two decades, with different types of mathematical communication being defined and emphasized as crucial for mathematical concept development (Brendefur & Frykholm, 2000; Brenner, 1994). Consequently, mathematical communication has been established as a fundamental process skill in the curricula of many countries that have demonstrated outstanding mathematics achievement at the international level, and has begun to be described as a fundamental mathematical literacy competency (Ata Baran & Kabael, 2021).

Mathematical communication competency represents one of the critical abilities that students must master, encompassing the capacity to convey ideas through symbols, tables, diagrams, and various mathematical representations (Jusniani & Nurmasidah, 2021). This competency serves as an essential tool for acquiring and processing mathematical information (Ariani, 2017). The Organization for Economic Co-operation and Development defines mathematical communication as the process whereby students make sense of mathematical problem situations and present solutions, explanations, or justifications to others (OECD, 2019). Furthermore, mathematical competencies consist of understanding, conducting, and using mathematical knowledge and activities to solve problems in different situations where mathematics plays certain roles (Niss & Højgaard, 2019). The National Council of Teachers of Mathematics identifies mathematical communication as one of five core mathematical competencies, alongside mathematical problem-solving, thinking and proving, and relating and representation competencies (NCTM, 2000).

The significance of mathematical communication in supporting students' mathematical thinking and problem-solving skills has been extensively documented in the literature (Thompson & Chappell, 2007; Ugurel, 2010). Research indicates that mathematical communication in the classroom directly affects students' cognitive understanding and constitutes an essential element in constructing mathematical knowledge (Ugurel, 2010). Moreover, mathematical communication functions as a basic competency primarily activated in solving real-life problems and plays an important role in enhancing mathematical literacy performance (Turner & Adams, 2012). Mathematical language and expressions serve as vital elements for effective communication, consisting of mathematical terms, drawings, models, charts, and graphs that are conventional in expressing mathematical content precisely, logically, and concisely (Niss & Højgaard, 2019). Mathematical representation, defined as a system of images, symbols, or specific objects with mathematical content, serves to depict, symbolize, or represent mathematical objects, relations, or procedures (Nguyen et al., 2024).

Despite the recognized importance of mathematical communication skills, field observations reveal concerning patterns of student passivity in learning environments. Interviews and observations conducted in Grade III classes at SD Negeri Gendongan 01 Salatiga indicate that while students enjoy practical aspects of mathematics, they demonstrate reluctance to engage in group discussions and prefer having teachers explain material comprehensively. This passive behavior stems from feelings of fear, embarrassment, nervousness, and reluctance to ask questions, ultimately hindering the development of mathematical communication abilities that constitute primary objectives of mathematics education according to NCTM standards (Ariani, 2017).

The literature demonstrates growing evidence supporting innovative pedagogical approaches to address these challenges. Fariha et al. (2024) investigated the influence of the RADEC learning model on mathematical literacy abilities and student engagement, revealing significant improvements in both areas. Similarly, Febriyanti et al. (2023) examined the effectiveness of Padlet-based RADEC model online learning in enhancing students' mathematical communication skills, demonstrating positive outcomes in digital learning environments. Predi et al. (2022) explored the effects of the RADEC learning model and student IQ on numerical abilities, finding significant correlations between the instructional approach and mathematical competency development.

To address identified pedagogical challenges, educational innovation through models such as RADEC (Read, Answer, Discuss, Explain, Create) has emerged as a promising solution (Widodo et al., 2024). This model is specifically designed to enhance student engagement through systematic stages of reading, answering, discussing, explaining, and creating works (Sopandi dan Sujana dalam Ramadhani et al., 2023). RADEC is considered an innovative learning solution that is easily comprehensible and adaptable to various educational contexts (Pratama dalam Widodo et al., 2024). Previous research has demonstrated the effectiveness of this model, with studies by Widodo et al. (2024) showing successful enhancement of higher-order thinking abilities and student communication skills, while research by Ardianti et al. (2023) proved RADEC's capability to improve students' numerical literacy.

Learning models serve as planned frameworks aimed at increasing student activity and independence in learning processes (Wafiqni & Nurani, 2019; Ponidi et al., 2021). The RADEC model represents an adaptation of inquiry learning designed to stimulate 21st-century skills in Indonesian students (Pebriansah et al., 2023). This student-centered model follows systematic stages of Reading, Answering, Discussing, Explaining, and Creating, focusing on conceptual understanding, collaboration, and problem-solving. Key characteristics of RADEC include promoting active student engagement, connecting material to real-life contexts, and facilitating opportunities for students to question, discuss, and draw conclusions (Suriani et al., 2024).

Given the persistent challenges in developing mathematical communication skills among elementary students and the promising evidence supporting innovative pedagogical approaches, this research aims to determine the effectiveness of the RADEC learning model in improving students' mathematical communication skills at the elementary school level. The significance of this study lies in its potential to provide evidence-based solutions for enhancing mathematical communication competencies, which are fundamental to mathematical literacy and 21st-century learning outcomes. By examining the implementation of RADEC in authentic classroom settings, this research contributes to the growing body of knowledge regarding effective instructional strategies for elementary mathematics education and offers practical implications for educators seeking to improve student engagement and communication skills in mathematics learning environments.

METHODS

This study employed a quasi-experimental research design to establish causal relationships between variables and determine the effectiveness of the RADEC learning model on students' mathematical communication skills (Arib et al., 2024). The research utilized a pretest-posttest non-equivalent control group design, which involved two groups: an experimental group receiving the RADEC learning model treatment and a control group receiving conventional instruction without the RADEC implementation. This design was selected to enable accurate measurement of treatment effects by comparing both groups' performance before and after the intervention while controlling for potential confounding variables.

The study was conducted at SD Negeri Gendongan 01 Salatiga, located in Tingkir District, Salatiga City, Central Java, Indonesia. The research population comprised all third-grade students totaling 75 individuals across multiple classes. From this population, a sample of 51 students was selected using purposive sampling technique, which involves deliberate sample selection based on specific criteria aligned with research objectives. The sample consisted of 27 students from Class III A designated as the experimental group and 24 students from Class III C serving as the control group. This sampling approach ensured comparable groups while maintaining practical feasibility for implementing the intervention and collecting comprehensive data.

Data collection employed multiple instruments to ensure comprehensive assessment and triangulation of findings. The primary instrument consisted of essay-based test questions designed to measure mathematical communication skills, administered as both pretest and posttest assessments. Prior to implementation, these instruments underwent rigorous validation procedures including validity and reliability testing conducted with 24 students from SD Negeri Kutowinangun 01 Salatiga, a comparable school serving as the pilot testing site. The validation process confirmed that all eight essay questions in both pretest and posttest demonstrated acceptable validity, with reliability analysis yielding a Cronbach's alpha coefficient of 0.955, indicating excellent internal consistency. Additional data collection methods included structured observations to monitor classroom interactions and student engagement patterns, as well as semi-structured interviews conducted with participants to gather qualitative insights regarding their learning experiences and perceptions of mathematical communication activities.

The research procedure involved systematic implementation across multiple phases to ensure methodological rigor. Initially, both groups completed identical pretests during the first meeting, lasting one instructional hour (35 minutes), to establish baseline mathematical communication abilities. Subsequently, the experimental group received instruction using the RADEC model while the control group continued with conventional teaching methods, with both interventions spanning three instructional hours (105 minutes) during the second meeting. The RADEC implementation followed the prescribed sequence of Read, Answer, Discuss, Explain, and Create phases, focusing on data presentation topics aligned with the Indonesian Independent Curriculum for third-grade mathematics. Following the intervention period, both groups completed posttests using equivalent assessment instruments to measure changes in mathematical communication skills.

Data analysis employed both descriptive and inferential statistical procedures using IBM SPSS Statistics version 27. Prerequisite analyses included normality testing using the Kolmogorov-Smirnov test to verify data distribution assumptions and homogeneity of variance testing using Levene's test to confirm equal variances across groups. The primary analysis utilized an Independent Sample T-Test to determine significant differences between experimental and control group performance on posttest measures. Qualitative data from interviews underwent thematic analysis using MAXQDA 24 software to identify patterns and themes related to student experiences and communication preferences. This mixed-methods approach enabled comprehensive examination of both quantitative outcomes and qualitative insights, providing robust evidence for evaluating the RADEC model's effectiveness in enhancing elementary students' mathematical communication skills within authentic classroom contexts.

RESULTS AND DISCUSSION

Results

Preliminary Findings from Student Interviews

Initial qualitative data collection through student interviews provided valuable insights into students' learning preferences and communication patterns in mathematics. The interview data, processed using MAXQDA 24 software, revealed significant patterns regarding student engagement in collaborative learning activities. Analysis of student responses indicated that the majority of participants expressed preference for individual learning approaches over group discussions or collaborative activities. This finding demonstrates a concerning tendency among students to avoid interpersonal communication and cooperative learning in mathematical contexts, which directly impacts the development of their mathematical communication skills.

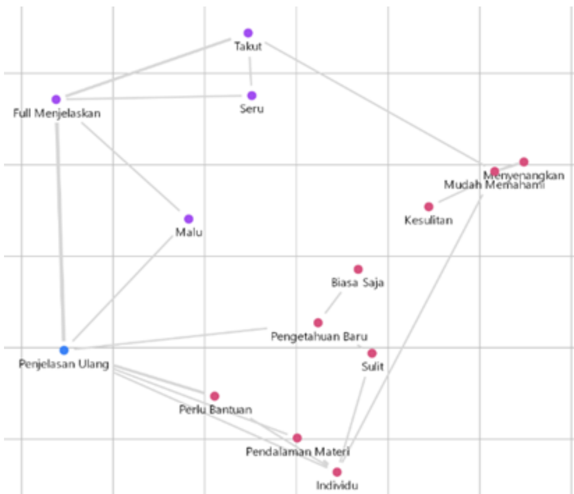

Figure 1. students consistently reported feeling more comfortable

The qualitative analysis illustrated in Figure 1 shows that students consistently reported feeling more comfortable when learning mathematics individually rather than participating in group discussions. This preference stems from various factors including lack of confidence, fear of making mistakes in front of peers, and insufficient experience with collaborative learning strategies. These findings establish the baseline context for understanding why mathematical communication skills require targeted intervention through innovative pedagogical approaches.

Implementation of Mathematics Learning

The implementation phase involved systematic delivery of mathematics instruction on data presentation topics to both experimental and control groups. The experimental group, consisting of 27 students from Class III A, received instruction using the RADEC learning model, while the control group of 24 students from Class III C received conventional mathematics instruction. Both groups participated in identical session structures, beginning with pretest administration during the first meeting (35 minutes), followed by the main instructional intervention during the second meeting (105 minutes). This standardized approach ensured comparable conditions for evaluating the differential effects of the RADEC model versus traditional teaching methods.

The RADEC implementation followed the prescribed sequence of Read, Answer, Discuss, Explain, and Create phases, with each stage designed to progressively develop students' mathematical communication competencies. During the Read phase, students examined mathematical problems and data presentation scenarios. The Answer phase required individual problem-solving before group interaction. The Discuss phase facilitated collaborative exploration of multiple solution strategies. The Explain phase demanded articulation of mathematical reasoning and justification of approaches. Finally, the Create phase challenged students to generate original mathematical representations and explanations. This systematic progression contrasted markedly with the conventional instruction received by the control group, which primarily involved teacher-directed explanation and individual practice.

Mathematical Communication Skills Assessment

Comprehensive assessment of mathematical communication skills was conducted through validated instruments measuring three key dimensions: written text capabilities, drawing/visual representation skills, and mathematical expression competencies. The posttest results provide clear evidence of differential performance between experimental and control groups across all measured competency areas.

Table 1. the distribution of mathematical communication skill levels

No	Category	Score Range	Experimental Group
1.	Very High	76-100	63%
2.	High	51-75	22%
3.	Low	26-50	11%
4.	Very Low	0-25	4%

Table 1 presents the distribution of mathematical communication skill levels across both groups following the intervention period. The data reveals substantial differences in performance distribution, with the experimental group demonstrating superior achievement in the highest performance categories. Specifically, 63% of experimental group students achieved very high performance levels (76-100 points) compared to only 50% of control group students. More significantly, the experimental group showed markedly lower representation in the lowest performance categories, with only 4% scoring in the very low range compared to 13% of control group students. These distributional differences suggest that the RADEC model implementation resulted in both elevated overall performance and reduced performance variability among students.

Statistical Analysis Results

Prior to conducting comparative analyses, prerequisite statistical assumptions were verified through normality and homogeneity testing. The normality assessment using the Kolmogorov-Smirnov test yielded significance values exceeding 0.05 for all measured variables (pretest control: 0.083, posttest control: 0.130, pretest experimental: 0.107, posttest experimental: 0.117), confirming normal distribution of data across all groups and measurement points.

Table 2. Tests of Normality

		Kolmogorov-Smirnov[a]		
	Class	Statistic	df	Sig.
Score	Pretest Control	.167	24	.083
	Posttest Control	.157	24	.130
	Pretest Experimental	.153	27	.107
	Posttest Experimental	.151	27	.117

Homogeneity of variance testing using Levene's test confirmed equal variances across groups, with significance values consistently exceeding 0.05 (based on mean: 0.294, based on median: 0.356, based on trimmed mean: 0.285). These results validated the appropriateness of parametric statistical procedures for subsequent comparative analyses.

The primary hypothesis testing employed an Independent Sample T-Test to examine differences in mathematical communication skills between experimental and control groups. The analysis revealed statistically significant differences between groups, with a t-value of -2.534, degrees of freedom of 49, and a two-tailed significance value of 0.015. Given that the obtained significance value (0.015) falls below the established alpha level of 0.05, the null hypothesis was rejected, and the alternative hypothesis was accepted.

Table 3. Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Score	Equal variances assumed	5.256	.026	-2.534	49	.015	-16.722	6.598
	Equal variances not assumed			-2.460	36.070	.019	-16.722	6.796

The magnitude of the treatment effect was substantial, with the experimental group achieving a mean score of 80.56 compared to the control group's mean score of 63.83, representing a mean difference of 16.72 points. The 95% confidence interval for this difference ranged from -29.982 to -3.463, indicating that the true population difference likely falls within this range with 95% confidence. These findings provide compelling evidence that implementation of the RADEC learning model resulted in statistically significant and practically meaningful improvements in students' mathematical communication skills.

Discussion

The findings of this study provide substantial evidence supporting the effectiveness of the RADEC learning model in enhancing elementary students' mathematical communication skills. The statistically significant improvement observed in the experimental group (mean score 80.56) compared to the control group (mean score 63.83) aligns with the theoretical foundations underlying the RADEC approach and represents a critical contribution to the evolving discourse on mathematical communication in education. This improvement is particularly significant given that mathematical communication has gradually gained importance over the past 20 years, with different types of mathematical communication being defined and emphasized as essential for mathematical concept development (Brendefur & Frykholm, 2000; Brenner, 1994).

The superior performance of students who received RADEC instruction can be critically analyzed through the lens of mathematical communication as a fundamental process skill. Mathematical communication has been established as a "process skill" in curricula of countries demonstrating outstanding international mathematics achievement and has evolved to be described as "a fundamental mathematical literacy competency" (Ata Baran & Kabael, 2021). The RADEC model's systematic progression through interconnected learning phases specifically targets these competencies by requiring students to actively engage with mathematical texts, problems, and representations. The Read phase particularly addresses the challenge of interpreting mathematical language, which consists of mathematical terms, drawings, models, charts, and graphs that are conventional in expressing mathematical content precisely, logically, and concisely (Niss & Højgaard, 2019). This phase directly supports students' development of mathematical language comprehension, which serves dual functions of communication and thinking (Niss & Højgaard, 2019).

The Answer phase's emphasis on individual cognitive processing before collaborative interaction reflects a sophisticated understanding of how mathematical communication develops. This approach recognizes that mathematical communication in the classroom directly affects students' cognitive understanding and serves as an essential element in constructing mathematical knowledge (Ugurel, 2010). By ensuring individual comprehension before group interaction, the RADEC model addresses the critical gap between passive reception and active construction of mathematical understanding. This is particularly important given that students require multiple qualifications beyond cognitive proficiency to effectively meet economic, political, and social demands for competencies (Levin, 2012).

The Discuss and Explain phases represent the most innovative aspects of addressing mathematical communication challenges identified in traditional instruction. These phases directly respond to OECD's (2019) definition of mathematical communication as the process of students making sense of mathematical problem situations and presenting solutions, explanations, or justifications to others. The observed improvements in students' written text, drawing, and mathematical expression abilities reflect the comprehensive nature of communication skills developed through these interactive phases, which facilitate information exchange between subjects through common systems of symbols, signs, or behavior via auditory and physical channels of communication (Boesen et al., 2018). This finding supports previous research by Febriyanti et al. (2023), who demonstrated that RADEC-based instruction significantly enhanced students' mathematical communication skills in digital learning environments.

A particularly critical analysis emerges when examining the Create phase in relation to mathematical representation theory. This phase requires students to generate original mathematical representations, directly addressing mathematical representation as a system of images, symbols, drawings, diagrams, graphs, charts, geometric sketches, or equations with mathematical content to depict, symbolize, or represent mathematical objects, relations, or procedures (Nguyen et al., 2024). The effectiveness of this approach is consistent with findings by Fariha, Marlina, and Ayuningtyas (2024), who reported significant improvements in both mathematical literacy abilities and student engagement following RADEC implementation. The creative element critically addresses the limitation of traditional instruction that often focuses on reproduction rather than generation of mathematical representations.

The substantial reduction in students scoring at very low performance levels (4% experimental vs. 13% control) warrants critical examination in light of equity and inclusivity concerns in mathematics education. This finding suggests that the RADEC model effectively addresses barriers that prevent struggling learners from developing mathematical communication competencies. Given that mathematical communication is significant in many countries' general education curricula (OECD Publishing, 2016), this improvement has profound implications for educational equity. The systematic structure of RADEC phases may provide necessary scaffolding that traditional approaches fail to offer, particularly for students who struggle with the ability to understand mathematical problems through written, oral, or visual mathematical statements and express mathematical ideas differently (OECD Publishing, 2016).

Comparison with previous research reveals critically important patterns that extend beyond simple effectiveness measures. Predi et al. (2022) found significant correlations between RADEC implementation and numerical ability development, while Widodo et al. (2024) demonstrated improvements in both higher-order thinking and communication skills. These convergent findings across multiple contexts suggest that the RADEC model addresses fundamental pedagogical principles embedded in the recognition that mathematical communication supports students' mathematical thinking and problem-solving skills (Thompson & Chappell, 2007; Ugurel, 2010). This consistency is particularly significant given that mathematical competencies consist of understanding, conducting, and using mathematical knowledge and activities to solve problems in different situations where mathematics plays certain roles (Niss & Højgaard, 2019).

The initial qualitative findings regarding students' preference for individual over collaborative learning provide a critical foundation for understanding the intervention's impact. The transformation from individual preference to effective collaborative mathematical communication represents a fundamental shift that aligns with research emphasizing mathematical communication as a basic competency primarily activated in solving real-life problems and playing an important role in enhancing mathematical literacy performance (Turner & Adams, 2012). This transformation is particularly significant because it demonstrates that structured pedagogical interventions can overcome affective barriers that often impede mathematical communication development.

A critical examination of the practical significance reveals that the 16.72-point mean difference represents more than statistical improvement—it signifies meaningful advancement toward NCTM's (2000) recognition of mathematical communication as one of five core mathematical competencies alongside problem-solving, thinking and proving, and relating and representation competencies. The observed improvements in students' ability to express mathematical ideas, justify reasoning, and engage in mathematical discourse directly address the importance of languages in mathematics learning (Erath et al., 2018) and demonstrate that innovative pedagogical approaches can effectively develop the mathematical language and expressions that are vital elements for mathematical communication.

However, several critical limitations must be acknowledged when interpreting these results within the broader context of mathematical communication research. The study's single-school context and relatively small sample size limit generalizability across diverse educational settings and cultural contexts. Additionally, the limited intervention period raises questions about the sustainability of observed improvements and whether the enhanced mathematical communication competencies will transfer to other mathematical domains and real-world applications. Future research should critically examine the long-term retention of RADEC-developed communication skills and investigate the model's effectiveness across different mathematical content areas, grade levels, and cultural contexts.

The findings contribute critically to the growing evidence base supporting pedagogical innovations that prioritize mathematical communication development. The RADEC model's demonstrated effectiveness in developing mathematical communication skills has profound implications for curriculum design, teacher professional development, and educational policy decisions. These implications are particularly important given the global emphasis on developing mathematical literacy and communication competencies as essential 21st-century skills. The study provides empirical support for the theoretical proposition that mathematical communication should be explicitly taught and systematically developed rather than assumed to emerge naturally from traditional mathematics instruction.

CONCLUSION

This study provides compelling evidence that the RADEC (Read, Answer, Discuss, Explain, Create) learning model significantly enhances elementary students' mathematical communication skills. The experimental group achieved a superior mean score of 80.56 compared to the control group's 63.83, with statistical analysis confirming significant differences ($p = 0.015$, $t = -2.534$). The intervention resulted in 63% of experimental students achieving very high performance levels versus only 50% in the control group, while simultaneously reducing the proportion of low-performing students from 13% to 4%.

The study contributes to mathematical education research by demonstrating that systematic, student-centered pedagogical approaches can effectively address longstanding challenges in developing mathematical communication competencies. The findings extend the theoretical understanding of how structured collaborative learning phases can transform students from passive recipients to active mathematical communicators. This research provides empirical support for integrating mathematical communication as a fundamental process skill rather than an incidental outcome of traditional instruction.

The practical implications are substantial for curriculum designers, educators, and policymakers seeking to enhance mathematical literacy outcomes. The RADEC model offers a replicable framework for developing the mathematical communication competencies emphasized in international education standards. Teacher professional development programs should incorporate RADEC implementation strategies to address the identified gap between theoretical recognition of communication importance and practical classroom application.

However, several limitations constrain the generalizability of these findings. The study was conducted in a single school context with a relatively small sample size over a limited intervention period. The sustainability of observed improvements and transferability across diverse mathematical content areas remain unexplored. Additionally, the research focused exclusively on Indonesian elementary contexts, limiting cross-cultural applicability.

Future research should investigate the long-term retention of RADEC-developed communication skills and examine the model's effectiveness across different grade levels, mathematical domains, and cultural contexts. Longitudinal studies exploring the relationship between enhanced mathematical communication skills and broader academic outcomes would provide valuable insights. Furthermore, comparative studies examining RADEC effectiveness relative to other innovative pedagogical approaches would strengthen the evidence base for optimal mathematical communication instruction strategies.

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