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Enhancing Sixth Graders' Mathematical Communication Skills Using the RADEC Learning Model: A Focus on Ratio Concepts

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ABSTRACT

Mathematical communication skills are critical for students to effectively understand and articulate mathematical concepts, directly impacting their numeracy and academic success. This study examines the effectiveness of the RADEC (Read, Answer, Discuss, Explain, Create) instructional model in improving the mathematical communication skills of sixth-grade students. A quasi-experimental design with a quantitative approach was employed, involving 60 sixth-grade elementary students. The experimental group (n = 30; 19 males, 11 females) received instruction through the RADEC model, while the control group (n = 30; 12 males, 18 females) was taught using the Problem-Based Learning (PBL) approach. Data were collected using a test consisting of five open-ended descriptive questions administered as pre- and post-tests. The N-Gain score was used to assess improvement, and the Mann-Whitney U test was applied to evaluate statistical significance. The RADEC group exhibited a moderate increase in mathematical communication skills, whereas the PBL group demonstrated only a low level of improvement. Statistical analysis confirmed a significant difference between the two groups (asymp. Sig. < 0.001, $\alpha = 0.05$), indicating that the RADEC model was more effective. These findings suggest that the RADEC model enhances students' mathematical communication more effectively than PBL, likely due to its emphasis on active engagement and collaborative learning. The model shows promise as a pedagogical approach and warrants further investigation regarding its impact on other mathematical competencies, including problem-solving, representation, critical thinking, and mathematical connections.

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1. INTRODUCTION

Mathematical communication is a foundational component of numeracy literacy, encompassing the ability to understand, express, and apply mathematical concepts across a range of real-life contexts. It includes not only performing operations but also the ability to interpret problems, explain reasoning, and represent ideas using appropriate mathematical tools and language (Kilpatrick et al., 2021). For students at the upper elementary level—particularly in Grade V—this skill entails expressing mathematical thinking clearly and logically through both oral and written forms. Effective mathematical communication requires a deep conceptual understanding, the ability to use various forms of representation such as diagrams, tables, graphs, and symbols, and the competence to explain problem-solving processes and solutions in precise mathematical language.

At this developmental stage, students are typically transitioning from concrete operational thinking to more abstract reasoning. According to Piaget's theory of cognitive development, children aged 7–11 years operate primarily within the concrete operational stage, where reasoning is based on tangible and observable objects. As they approach the formal operational stage, usually around age 11 and beyond, they begin to engage in abstract and hypothetical thinking (Santrock, 2022). Grade V students, therefore, occupy a transitional cognitive phase that requires deliberate pedagogical support to facilitate deeper understanding. Mathematical communication, supported by visual and symbolic representations, can serve as a bridge between their concrete experiences and the abstract concepts they are expected to master.

This transitional period is critical not only for building higher-order mathematical skills but also for developing essential 21st-century competencies such as critical thinking, problem-solving, and collaboration. Suherman et al. (2023) emphasize that the ability to communicate mathematical thinking is integral to the formation of critical and creative reasoning skills, as students move beyond procedural fluency toward conceptual understanding. Mathematical communication enables learners to articulate their thought processes, engage in mathematical discussions, and construct logical arguments in both individual and collaborative settings. Such engagement not only strengthens academic competence but also enhances self-confidence and prepares students to confront real-world problems with a mathematical lens (National Council of Teachers of Mathematics [NCTM], 2020).

Importantly, effective mathematical communication contributes to meaningful learning by helping students relate abstract mathematical ideas to real-life experiences. Teachers, therefore, must design instructional strategies that explicitly promote this skill, integrating communication as both a learning objective and a process throughout mathematical instruction (Siregar & Nasution, 2024). This instructional focus is especially relevant in contexts like Indonesia, where the development of students' numeracy skills remains a pressing educational challenge.

Recent data underscore persistent concerns regarding the state of mathematical competence among Indonesian students. According to the Programme for International Student Assessment (PISA), Indonesia's average mathematics score declined from 379 in 2018 to 366 in 2022, indicating a widespread deficiency in foundational mathematical literacy (Organisation for Economic Co-operation and Development [OECD], 2023). These results suggest significant gaps in students' abilities to comprehend basic concepts, interpret graphical data, and perform fundamental arithmetic operations.

Further evidence from the Ministry of Education, Culture, Research, and Technology's Asesmen Nasional (National Assessment) highlights similar issues. School-level performance data indicate that many elementary students remain in the lower proficiency bands (red and yellow categories) for numeracy literacy. This implies that a considerable proportion of students are failing to meet the minimum expected standards in terms of understanding core mathematical ideas, demonstrating fluency in basic operations, and applying mathematical reasoning in practical situations.

These national trends are mirrored in the classroom experiences of Grade V students. Observational data and assessments in multiple schools indicate that many students struggle with the core components of mathematical communication, such as articulating problem-solving strategies, accurately using mathematical representations, and connecting mathematical ideas to real-life situations. For example, some students are unable to explain their reasoning clearly in oral or written form, misinterpret graphs and tables, or apply mathematical procedures without a conceptual understanding of their relevance. Teachers at higher levels of education often report that students arrive with inadequate foundational numeracy skills, compounding the difficulty of advancing their mathematical understanding.

Addressing these challenges requires a deliberate and well-structured approach to teaching and learning. Instructional models play a crucial role in shaping students' learning experiences and can serve as powerful tools to support the development of mathematical communication skills. The selection and implementation of effective learning models must be aligned with specific learning objectives, tailored to students' cognitive development stages, and adaptable to the realities of classroom contexts (Joyce et al., 2018). In this regard, student-centered learning models that promote active engagement, collaboration, and reflective thinking are especially relevant.

Interactive learning models such as group discussions, collaborative problem-solving, and structured peer dialogue provide opportunities for students to verbalize their thinking, explain solutions, and learn from the perspectives of their peers. These activities help students internalize mathematical concepts while developing the capacity to express themselves logically and coherently. Models that emphasize authentic, real-life problems—such as Problem-Based Learning (PBL)—have been shown to enhance not only content understanding but also students' mathematical communication and representation skills. PBL encourages students to work collaboratively to analyze complex problems, explore potential solutions, and present their findings using appropriate mathematical tools and language (Hmelo-Silver, 2004).

Another promising instructional approach is the RADEC model (Read, Answer, Discuss, Explain, Create), which integrates elements of reading comprehension, inquiry, collaborative discourse, and creative synthesis. The RADEC model guides students through a scaffolded process of knowledge construction: beginning with understanding a problem or concept (Read), generating initial responses (Answer), engaging in structured dialogue (Discuss), articulating understanding (Explain), and finally producing a meaningful output (Create). This model supports gradual and reflective learning, allowing students to deepen their understanding while developing fluency in mathematical communication (Hermawan et al., 2021).

Despite the growing body of research supporting both PBL and RADEC as effective pedagogical approaches, comparative studies examining their relative impact on mathematical communication—especially in the context of Indonesian elementary education—remain limited. Most existing studies focus on general mathematical competence or problem-solving abilities, leaving a gap in the literature regarding how different models influence specific communication skills.

To address this gap, the current study investigates the comparative effectiveness of the RADEC and PBL instructional models in enhancing the mathematical communication skills of sixth-grade students. The study is guided by the following research questions:

1. How does the RADEC model improve the mathematical communication skills of Grade VI students?
2. How does the PBL model improve the mathematical communication skills of Grade VI students?
3. Is there a significant difference in the effectiveness of the RADEC and PBL learning models in improving mathematical communication skills?

This research aims to make a meaningful contribution to educational practice and policy by providing empirical evidence on the use of instructional models to support the development of mathematical communication. The findings are expected to inform teachers, curriculum developers, and education policymakers about effective strategies for enhancing mathematics instruction, particularly at the primary level. Furthermore, the study supports the broader goal of improving students' mathematical literacy and equipping them with the skills necessary for academic and real-world success.

Ultimately, the integration of innovative models such as RADEC and PBL into the primary school curriculum holds significant promise for transforming classroom practice. These models promote student-centered learning environments, encourage meaningful engagement with mathematical ideas, and foster essential competencies such as communication, critical thinking, and collaboration. When supported by appropriate teacher training and instructional design, these approaches can help address persistent learning gaps and elevate the overall quality of mathematics education in Indonesia.

2. METHODS

This study was conducted as field research at a public elementary school located in Lembang District, West Bandung Regency, West Java Province. It employed a quantitative approach using a quasi-experimental method, specifically the pretest-posttest control group design without random assignment. In this design, participants were divided into an experimental group and a control group, with the selection of samples conducted naturally, meaning without randomization. This setup allowed for the measurement of differences in student performance before (pretest) and after (posttest) the intervention (Borg, Gall, & Gall, 2015; Cohen, 2015). The experimental group received instruction using the RADEC learning model, while the control group was taught using the Problem-Based Learning (PBL) model. The structure of the research design is outlined as follows:

O X O
O Y O
Description:
O : Giving both pretest and posttest
X : Experiment Class (RADEC learning model)
Y : Control class (PBL learning model)

2.1 Sampling and Selection Process

The participants in this research were sixth-grade students from a public elementary school in Lembang District, with a total of 54 students involved. The population targeted in this study comprised all sixth-grade students in elementary schools across West Bandung Regency during the 2024–2025 academic year. The experimental and control groups were established by selecting two existing Grade VI classes from the same public elementary school in Lembang District. Due to the quasi-experimental nature of the research design, students were not randomly assigned to the experimental group (which received the RADEC model) or the control group (which received the PBL model). Instead, the grouping was based on the school's existing class divisions. This approach reflects a natural setting where students are already grouped according to their school schedules, thus minimizing distractions and providing a realistic picture of how these teaching models would function in a typical classroom environment. Although no randomization was used, efforts were made to ensure equality between the groups by selecting classes that had similar academic performance and demographic characteristics to reduce bias.

To ensure comparability between the two groups, a pretest was conducted so that the initial condition of each group was known and the extent to which the ability of both groups improved from their initial condition was known.

2.2 Instrument Reliability and Validity

The data collection used in this study is test result data on students' mathematical communication skills developed by the author in the form of a description question totaling 5 questions. The preparation of questions refers to the indicators of mathematical communication skills revealed by Losi et al., (2021). These indicators are: (1) drawing ability, which includes the ability of students to express mathematical ideas in the form of images, diagrams, graphs, tables and algebraically, (2) written text ability, which is the ability to provide explanations and reasons in mathematics with correct and easy-to-understand language and (3) mathematical expression ability, which is the ability to create mathematical models. to find out the form of numeracy difficulties faced by the subject and indicators of numeracy ability. The validity test was carried out to evaluate the suitability of the research measuring instrument with the instrument development standards used in measuring the research variables. The mathematical problem solving ability test instrument was tested for validity by the supervisor, a professor who has expertise in the field. He was chosen because he has extensive teaching and research experience, as well as a deep understanding of the research context. The developed instruments were evaluated by the classroom teacher, who was also involved in content validation by providing an assessment of the developed instruments. The experience of these teachers depended on their understanding of the depth of mathematics subject matter and the characteristics of fifth-grade students.

2.3 Treatment Monitoring

To ensure that the RADEC and PBL models were implemented as intended, regular classroom observations were conducted by the researcher during the study. These observations allowed the researcher to monitor the fidelity of the teaching models' implementation. Additionally, teacher feedback was collected through informal discussions after each lesson, providing insight into any challenges faced during implementation. Teachers were also given a brief training session on the specific requirements and methodologies associated with each learning model to ensure consistency across classes. Any deviations from the prescribed implementation were addressed promptly to maintain the integrity of the study.

2.4 Justification of Statistical Choices

Test-based data can be utilized for statistical procedures such as calculating the mean, median, and N-Gain scores to assess the improvement in learning outcomes (Bahtiar et al., 2020). Data analysis refers to the systematic process of organizing, processing, and interpreting collected data to address the research questions or to evaluate predetermined hypotheses. Depending on the nature of the data, this analysis can follow either a quantitative or qualitative approach. Within quantitative research, the analysis typically involves both descriptive and inferential techniques aimed at identifying patterns or relationships among variables (Sugiyono, 2017).

In this research, the enhancement of students' mathematical communication skills in both the experimental and control groups was assessed through descriptive statistical analysis, particularly by employing the N-Gain approach. The descriptive analysis involved the presentation of data using various formats such as tables, charts, pie diagrams, and numerical summaries, including central tendency measures (mean, median, mode, and quartiles), percentages, and dispersion indicators such as standard deviation (O'Reilly et al., 2018). Outputs from descriptive statistics typically include details such as sample size (N), range of scores (minimum and maximum), average values, standard deviation, as well as skewness and its associated standard error (Leech, Barrett, & Morgan, 2015).

Beyond descriptive analysis, the study also incorporated inferential statistical procedures to ensure the validity of comparisons between the two instructional models. These included normality and homogeneity tests, followed by the application of the Mann-Whitney U test—a non-parametric statistical method—using SPSS software version 29. This sequence of tests was utilized to examine whether the RADEC model significantly outperformed the PBL model in fostering improvements in students' mathematical communication skills.

3. FINDINGS AND DISCUSSION

The results of research in the experimental class in the form of pretest scores of students' mathematical communication skills can be seen in the following descriptive statistics table:

Table 1. Experimental Class Pretest Results

	N	Minimum	Maximum	Mean	Std. Deviation
Pretest_Eks	30	0	60	16.17	12.504
Valid N (Listwise)	30				

As shown in the table, the pretest scores of mathematical communication skills in the experimental class ranged from a minimum of 0 to a maximum of 60. The mean pretest score was 16.17, with a standard deviation of 12.50, indicating that prior to the intervention, students generally exhibited low mathematical communication abilities with notable variability among individual performances.

The posttest results for the experimental group, obtained after the implementation of the RADEC learning model, are presented in the following table of descriptive statistics. These results provide insights into the extent of learning progress achieved through the application of this instructional approach.

Table 2. Experimental Class Posttest Results

	N	Minimum	Maximum	Mean	Std. Deviation
Posttest_Eks	30	10	100	16.17	22.194
Valid N (Listwise)	30				

The table indicates that posttest scores for mathematical communication skills in the experimental group ranged from a minimum of 8 to a maximum of 100. The average score obtained was 61.17, with a standard deviation of 22.19. These figures suggest considerable variation in student performance, reflecting differing levels of mastery following the implementation of the RADEC instructional model.

To evaluate the extent of improvement in students' mathematical communication abilities, N-Gain scores were calculated using the pretest and posttest results. This analysis was performed using SPSS software version 29, which provided a detailed output of the gain scores for each student in the experimental class. The results of this analysis are presented as follows:

Table 3. N-Gain Experimental Class

	N	Minimum	Maximum	Mean	Std. Deviation
N_Gain_Eks	30	10	100	.5497	.24300
N_Gain_Persen_Eks	30	10.00	100.00	54.9681	24.29958
Valid N (Listwise)	30				

The table shows that the highest N-Gain score achieved in the experimental group was 1.00, equivalent to 100% when converted to a percentage. Meanwhile, the lowest N-Gain score recorded was 0.10, or 10%. The average N-Gain score for the experimental class stood at 0.55, which corresponds to approximately 55% in percentage terms. These results indicate a relatively wide range of individual student improvement, with a generally moderate to high level of gain across the group.

To assess the significance of this improvement, N-Gain values are categorized into levels of low, medium, and high. This classification helps interpret the effectiveness of the learning intervention in a more meaningful way. The criteria used to determine the N-Gain category for each score are:

Table 4. Normalized Gain Criteria

Nilai N-Gain	Interpretation
$g > 0,7$	High
$0,3 \leq g \leq 0,7$	Medium
$g < 0,3$	Low
$g = 0,00$	No increase
$-1 \leq g < 0,00$	There was a decrease

Source: Sukarelawan, Indratno, Ayu, 2024:11

Based on these criteria, by looking at the average N-Gain score in the experimental class of 0.55 greater than 0.3 and smaller than 0.7, it can be said that the increase in students' mathematical communication skills in the experimental class is in the medium category. The N-Gain score can also illustrate the level of effectiveness of treatment on the dependent variable, with the following criteria:

Table 5. Criteria for Determining the Effectiveness Level

Persentase (%)	Interpretation
< 40	Not Effective
40 - 55	Less effective
56 -75	Moderately Effective
> 76	Effective

Source: Sukarelawan, Indratno, Ayu, 2024:11

Based on these criteria, by looking at the average percentage of N-Gain in the experimental class of 55% and this figure is in the interval 56 -75, it can be said that the RADEC learning model is quite effective in improving the mathematical communication skills of grade VI elementary school students on Ratio material.

The results of the pretest and posttest scores of students' mathematical communication skills in the control class can be seen in the following descriptive statistics table:

Table 6. Pretest and Posttest Results of Control Class

	N	Minimum	Maximum	Mean	Std. Deviation
Pretes_Control	30	0	45	23.50	8.823
Posttest_Control	30	25	65	47.33	12.158
Valid N (Listwise)	30				

Based on the table, the pretest scores of mathematical communication skills in the control group ranged from a minimum of 0 to a maximum of 40. The mean score for this assessment was 23.50, with a standard deviation of 8.82, indicating a relatively low initial level of students' mathematical communication abilities and a moderate spread of scores. In the posttest, the lowest score observed was 25 and the highest was 65. The average posttest score increased to 47.33, accompanied by a higher standard deviation of 12.16, suggesting both an improvement in performance and a wider range of outcomes among students.

These results point to measurable progress in students' abilities after receiving instruction via the Problem-Based Learning (PBL) model. However, the variation in posttest scores also reflects differences in how individual students responded to the learning process.

To further analyze the extent of this improvement, the N-Gain scores were calculated using pretest and posttest data on students' mathematical communication performance in the control class. This analysis was conducted using SPSS software version 29, and the outcomes are presented as follows:

Table 7. Descriptive Statistics N-Gain of Control Class

	N	Minimum	Maximum	Mean	Std. Deviation
N_Gain_Control	30	.06	.65	.3027	.16887
N_Gain_Persen_Control	30	6.25	65.00	30.2662	16.88737
Valid N (Listwise)	30				

The table reveals that the maximum N-Gain score achieved by students in the control group was 0.65, which translates to 65% in percentage terms. Conversely, the minimum score was 0.06, or approximately 6.25%. The overall average N-Gain for the control group was 0.30, equivalent to about 30.26% when expressed as a percentage. These figures indicate a varied level of improvement among students following the PBL-based instruction.

Referring to the classification guidelines provided in Table 4, the average N-Gain score of 0.30 places the control group within the medium category of learning improvement. This implies that the Problem-Based Learning (PBL) model facilitated a moderate enhancement in students' mathematical communication skills, particularly when addressing ratio problems in a sixth-grade context. However, the variation between the maximum and minimum values suggests inconsistency in how students responded to the instructional model.

In addition, the average N-Gain percentage was analyzed using the interpretive criteria listed in Table 5. The 30% average places the control group at the lower threshold of the medium category, highlighting that the gains, while measurable, were not substantial. This finding points to the limited impact of the PBL approach in significantly elevating students' abilities to articulate and reason mathematically, particularly in the context of complex or abstract concepts such as ratio.

To determine whether the RADEC instructional model produced more effective outcomes than the PBL approach, a comparative statistical analysis of the N-Gain scores between the experimental and control groups was conducted. As an initial step, a normality test was performed to evaluate whether the data in both groups followed a normal distribution. The test was carried out using SPSS Version 29, and the results are detailed as follows:

Table 8. Normality Test Results

		Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
	Class	Statistic	df	Sig.	Statistic	df	Sig.
N-Gain	RADEC	.143	.30	.120	.945	30	.217
	PBL	.200	.30	.004	.924	30	.033

a. Lilliefors Significance Correction

The table displays the results of both the Kolmogorov-Smirnov and Shapiro-Wilk normality tests. Given that the sample size consists of 60 participants—exceeding the threshold of 30—the Kolmogorov-Smirnov test is deemed appropriate. The significance (sig) value for the N-Gain score in the RADEC group is 0.12, which exceeds the α level of 0.05, indicating that the data is normally distributed. In contrast, the PBL group's N-Gain score yields a sig value of 0.004, which is below $\alpha = 0.05$, suggesting that the data does not follow a normal distribution.

Since one of the datasets does not meet the assumption of normality, a non-parametric statistical approach is required. Therefore, the Mann-Whitney U test was selected to compare differences in N-Gain scores between the experimental and control groups.

This analysis was carried out using SPSS version 29, and the output from the Mann-Whitney U test is presented as follows:

Table 9. Mann-Whitney Test Results

	N-Gain
Mann-Whitney U	184.000
Wilcoxon W	649.000
Z	-3.938
Asymp. Sig. (2-tailed)	<,001

a. Grouping Variable: Kelas

The test results demonstrate that the Asymp. Sig. (2-tailed) value is less than 0.001, which is well below the significance level of $\alpha = 0.05$. This outcome supports the acceptance of the research hypothesis, signifying a statistically significant difference in the effectiveness of the RADEC and PBL instructional models in fostering sixth-grade students' mathematical communication skills on the topic of Ratio.

To identify which of the two models—RADEC or PBL—is more effective in enhancing students' mathematical communication, a comparison of the median N-Gain scores between the two groups was conducted. The details of this comparison are presented in the table below:

Table 10. Median Value of N-Gain of RADEC and PBL Classes

		N_Gain_Radec	N_Gain_PBL
N	Valid	30	30
	Missing	0	0
Median		.5670	.2405
Mode		.56[a]	.19
Sum		16.49	9.08

a. Multiple modes exsit. The smallest value is shown

The table indicates that the median N-Gain score for the RADEC group is 0.56, whereas the median for the PBL group is 0.24. Based on these values, it can be concluded that the RADEC learning model demonstrates greater effectiveness compared to the PBL model in enhancing the mathematical communication skills of sixth-grade elementary students, particularly in learning the topic of Ratio.

Discussion

The findings indicate a statistically significant difference in the effectiveness of the RADEC and PBL instructional models in enhancing sixth-grade elementary students' mathematical communication skills on the topic of ratio. An analysis of the median N-Gain scores suggests that the RADEC model demonstrates greater effectiveness compared to the PBL model in supporting the development of students' mathematical communication in this subject area. This result may be attributed to the structured and reflective nature of the RADEC model, which allows students to connect prior knowledge with new concepts more systematically. Furthermore, the emphasis on elaboration and confirmation stages within RADEC appears to reinforce students' ability to express mathematical ideas clearly and accurately.

Learning with the RADEC model is more effective than the PBL model due to students' higher readiness to learn, where in this model there is a Read (reading material provided by the teacher or watching videos) and Answer (answering essential questions) stage which is carried out by students at home before learning at school. Whereas in the PBL model, students are not specifically assigned to read the material and answer essential questions at home. In line with the results of research that shows there is a positive correlation between learning readiness and math learning outcomes (Ferry Sukma et al., 2021).

The PBL model has facilitated students' experience in solving real problems through investigation and group learning. The RADEC model has also facilitated this activity at the small group discussion and large group discussion stages. However, the RADEC learning model also facilitates students to make products or works according to their respective creativity at the Create stage and this stage is not found in the PBL learning model. In line with John Dewey's Learning by Doing theory, the most effective learning occurs through direct experience and active involvement. Learning is not just a passive process of absorbing information, but involves activities that allow students to solve real problems, interact with their environment, and reflect on their experiences. This approach integrates doing, being, and knowing as one unit in the learning process (Quay, 2023).

Mathematical communication skills involve the ability to convey mathematical ideas and understand the ideas of others. This improvement is significant in the RADEC model because this model encourages active student discussion and interaction, as outlined by Bahtiar et al. (2020), that mathematical communication is important to develop students' mathematical literacy skills. The RADEC model, which emphasizes the stages of reading, answering, discussing, explaining and creating, is more effective because it encourages intensive two-way communication (Mohamed et al., 2022). This supports students in developing their communication skills by connecting mathematical concepts to real life. While PBL is effective for the development of problem-solving skills, this approach is less optimal in encouraging students to actively discuss or explain their ideas (Qin et al., 2019). Therefore, RADEC is superior in improving mathematical communication.

Furthermore, the RADEC model is structured to foster active student engagement and critical thinking throughout the learning process. According to Satria and Sopandi (2019), this model enhances students' critical thinking by guiding them through sequential stages—reading, answering, discussing, explaining, and creating—each of which promotes deeper understanding and reflection. Research involving the RADEC model has shown significant improvements in students' conceptual comprehension and critical thinking across various subjects (Setiawan et al., 2020). For example, applying RADEC in lessons on the water cycle has been found to substantially increase students' mastery of concepts. This is largely attributed to the model's design, which encourages scientific thinking and active student involvement.

The findings of this study also align with earlier research emphasizing the collaborative strengths of the RADEC model. Specifically, the "Discuss" and "Explain" phases offer students opportunities to articulate their thoughts, share solutions, and critically assess ideas developed during group discussions. These stages are particularly well-suited to supporting the development of mathematical communication, the core competency examined in this study. Through these activities, students not only gain a solid grasp of the content but also learn to communicate their reasoning clearly and coherently (Satria & Sopandi, 2019).

Based on the research results obtained data that there is an increase in the level of mathematical communication skills of students in the experimental class, namely the class that gets learning with the RADEC model with an average N-Gain score of 0.66 which when percented is around 65.75%. This value shows that the level of increase is at a moderate level and the effectiveness of the RADEC learning model in improving the mathematical communication skills of grade VI elementary school students on Ratio material is at a fairly effective level. Not much different from previous research which shows that the classification of the N-Gain score of critical thinking skills of students who get RADEC model learning is 0.513 and the score is included in the moderate category (Yulianti, Lestari, Rahmawati, 2022).

However, the findings of this study contrast with those reported in earlier research. Apriansah et al. (2024) found that the average N-Gain score for students' conceptual understanding of Energy Transformation material in an experimental group using the RADEC learning model was 86.904, or approximately 87%. According to the interpretation criteria for N-Gain effectiveness, this result falls into the "effective" category.

This discrepancy suggests that the RADEC model may be more effective in enhancing students' understanding of scientific concepts than in developing their mathematical communication skills. One possible explanation is that science content may be more accessible for students, as it is often taught using direct instruction and demonstrations, which help clarify abstract concepts and facilitate the application of knowledge. In contrast, mathematics instruction typically requires students to work through abstract problems more independently, often involving symbolic reasoning and contextual problem solving.

Moreover, mathematical communication is inherently more complex than conceptual understanding. Various factors influence students' ability to communicate mathematically, including their ability to extract and articulate known and unknown information from problems, concentration during instruction, depth of understanding, task difficulty, and emotional readiness when solving problems (Hasbi et al., 2023). Additionally, the effectiveness of the RADEC model in mathematics depends significantly on how teachers design and deliver materials—such as pre-lesson prompts and student worksheets (LKPD). The level of difficulty embedded in the assessment tools used to evaluate mathematical communication skills can also affect the results.

The statistical analysis supports a significant difference in the median N-Gain scores between the RADEC and PBL groups. Specifically, the RADEC group achieved a median N-Gain of 0.56, while the PBL group obtained a median of 0.24. This outcome underscores the greater effectiveness of the RADEC model in enhancing students' mathematical communication, particularly in the context of learning ratio concepts in sixth grade.

This difference also holds practical implications. The notably higher median N-Gain score in the RADEC group indicates that students exposed to this model experienced more substantial improvement in their ability to express mathematical ideas clearly and coherently, compared to those taught with the PBL approach. These findings highlight the potential of RADEC to support deeper engagement with mathematical communication when implemented effective.

The higher median N-Gain for RADEC may be due to its structured approach that provides students with clear, sequential stages: Read, Answer, Discuss, Explain, and Create. These stages likely offer students more explicit opportunities to practice and refine their communication skills. For instance, the "Discuss" and "Explain" stages in RADEC allow students to articulate their understanding, which is critical for developing strong communication skills in mathematics.

The results of the study indicate that learning with the Problem-Based Learning (PBL) model is less effective than the RADEC model in improving the mathematical communication skills of Grade VI elementary school students on the topic of Ratios. While the PBL model offers advantages in providing real-world problem-based learning experiences, several factors emerge from this study that explain why PBL is less optimal in enhancing students' mathematical communication skills.

One key factor is the lack of preliminary preparation in the PBL model. In the PBL approach, students are immediately presented with complex real-world problems without undergoing a proper preparatory phase, such as pre-reading the material or responding to essential questions at home, as is facilitated in the RADEC model. This lack of initial preparation leads to challenges for students in the control group (PBL class) in understanding the presented problems due to their insufficient foundational understanding of the concepts. This unpreparedness may hinder their ability to develop effective problem-solving strategies or articulate their ideas within a structured mathematical communication framework.

Moreover, the PBL model places more emphasis on developing problem-solving skills and group work than on improving specific mathematical communication skills. In this model, students tend to collaborate more in finding solutions but are not explicitly directed to practice expressing their mathematical ideas, either in writing or verbally. This contrasts with the RADEC model, which includes stages such as "Create," specifically engaging students in creating products that reflect their mathematical understanding.

Another contributing factor is the insufficient emphasis on the reflection process in the PBL model. Reflection or discussion of learning outcomes is not conducted in depth, largely due to limited learning time and the focus on problem-solving. This leaves students with fewer opportunities to reflect on their problem-solving process, which could strengthen their mathematical communication skills. In contrast, the RADEC model's "Discuss" stage provides more space for students to reflect on their understanding through both small and large group discussions.

In essence, although the PBL model holds considerable potential for enhancing problem-solving skills and teamwork, its implementation requires more thorough preparation and support, particularly for students at the primary education level. Modifications to the PBL model are needed to increase its effectiveness in developing mathematical communication skills.

Although the Problem-Based Learning (PBL) model was found to be less effective in enhancing mathematical communication skills in this study, it remains a powerful approach for fostering students' problem-solving abilities. PBL is structured to involve learners in addressing complex, real-life problems, thereby encouraging critical and creative thinking in the pursuit of solutions. This model supports learners in identifying, analyzing, and resolving issues in ways that are relevant and applicable to real-world contexts.

A key strength of the PBL approach lies in its capacity to develop in-depth problem-solving competencies. Within the field of mathematics education, PBL immerses students in authentic problem scenarios, enabling them to relate mathematical theories to practical situations. This experience enhances their capacity to apply mathematical understanding to solve complex, non-routine tasks. Moreover, the model encourages students to engage in processes such as question formulation, designing strategic approaches to problems, and assessing the effectiveness of their solutions. As a result, PBL contributes meaningfully to cultivating comprehensive problem-solving skills. However, existing literature has suggested that, despite these advantages, PBL may not be as effective in promoting students' active participation in discussions or in articulating their mathematical thinking (Qin, [year]).

Beyond the structural distinctions between the RADEC and PBL models, the outcomes observed in this study may also have been influenced by external factors, including the teacher's instructional competence, the learning environment within the classroom, and the students' level of motivation. These contextual elements play a significant role and should be taken into account when evaluating the success of instructional models in enhancing students' mathematical communication proficiency.

Teacher competence is a critical factor influencing the successful implementation of learning models, whether RADEC or PBL. In the context of the RADEC model, teachers need to be skilled in designing learning materials, structuring pre-learning questions, and effectively managing group discussions. Teachers must also be capable of guiding students through the "Create" stage, which requires creativity and active involvement in producing products that demonstrate their mathematical understanding. In the PBL model, teachers must be adept at facilitating group discussions, providing guidance without being overly directive, and ensuring that every student is actively engaged in problem-solving. If teachers are not skilled in managing the PBL process, students may become confused or fail to receive adequate direction, diminishing the model's effectiveness. Additionally, teachers' limitations in designing relevant and challenging problems can affect students' motivation and understanding.

A conducive classroom environment is essential to support the learning process, especially in the PBL model, which relies on collaboration among students. A classroom environment that is disorganized or less supportive of group interaction can obstruct the implementation of problem-based learning. In such conditions, students may struggle to focus, communicate with group members, or understand the material being taught. In contrast, the RADEC model, which also involves group discussions and creative activities, benefits from a positive classroom environment that provides space for students to express themselves more freely and participate actively. Teachers must ensure that the classroom environment fosters a sense of comfort, safety, and inclusivity, enabling all students to engage optimally in the learning process.

Student motivation is another significant factor affecting learning success. Motivated students tend to be more active in exploring the material, answering questions, and participating in group discussions. In the RADEC model, the "Read" and "Answer" stages can enhance students' motivation by making them feel more prepared for class. The "Create" stage also allows students to express their creativity, which can increase their interest in learning. However, with the PBL model, student motivation may be more challenging, particularly if the problems posed are not relevant to their interests or experiences. Problems that are overly complex or abstract can cause students to lose interest and find the task difficult. In such cases, teachers must play an important role in motivating students by providing clear directions, positive encouragement, and reinforcing the relevance of the problem to their lives.

In addition to the factors already mentioned, support from both the school and home environments can significantly affect learning outcomes. For example, the availability of adequate learning resources at school, such as reference books, visual aids, or educational technology, can support students in understanding the material and completing assignments. On the other hand, parental support, such as encouraging students to read materials or answer essential questions at home, can further enhance the effectiveness of the learning process.

Thus, external factors such as teacher competence, classroom environment, student motivation, and support from school and home environment have a significant influence on the effectiveness of learning models. To improve learning outcomes, comprehensive efforts need to be made, including teacher training in managing learning models, creating a conducive classroom environment, motivating students through relevant approaches, and involving the active role of parents and schools. By optimizing these external factors, it is expected that learning, both with RADEC and PBL models, can run more effectively and provide better results.

This study may have limitations in terms of the number or characteristics of the sample, the breadth of material with the time available, the intensity of treatment in the experimental class and control class which was only conducted twice. These limitations may impact on the accuracy of the generalization of the research results and the effectiveness of the implementation of the tested learning model.

1. Influence of Sample Size and Characteristics

   Limited sample size or characteristics may limit the representativeness of the research results. If the research sample is not large enough or less varied in terms of academic, social, and economic background, the results obtained may not reflect the general population conditions. This may cause bias in the interpretation of the effectiveness of RADEC and PBL models on students' mathematical communication skills.
2. Influence of Time and Material Coverage

   Limited time to implement the learning model may affect the depth of students' understanding of the material. Two meetings may not be enough to provide a comprehensive and sustainable learning experience, especially in practicing mathematical communication skills that require repetition and habituation. The imbalance between the breadth of the material and the time allocation can also cause students to feel rushed in understanding the concepts, resulting in less than optimal learning outcomes.
3. Effect of Treatment Intensity

   The low treatment intensity in the experimental and control classes, with only two meetings, limits the opportunity to test the effectiveness of the learning model in depth. Learning with new approaches such as RADEC and PBL requires adaptation time for students and teachers. With limited intensity, it is difficult to ensure that students have fully understood and mastered the applied learning approach.

To overcome these limitations and improve the validity and reliability of the results, here are some mitigating suggestions for future research:

1. Increase Sample Size and Variety

   Future research should involve a larger and more diverse sample size to ensure more representative results. Sampling that includes students from various academic and socio-economic backgrounds may provide a more comprehensive picture of the effectiveness of the learning model.
2. Adjusting the Proportion of Time and Material

   Providing a longer time and proportional to the scope of the material to be taught is very important to provide an in-depth learning experience. Future research can extend the duration of the treatment, for example by allocating 6-8 meetings, to provide more opportunities for students to understand concepts and practice their mathematical communication skills.
3. Increasing the intensity of the treatment

   Increasing the intensity of treatment with more learning sessions can help students to get used to the learning model used. It also provides time for teachers to optimize the application of RADEC or PBL models, so that the results obtained better reflect the effectiveness of the model as a whole.
4. Teacher Mentoring and Competency Development

   In future research, intensive training for teachers in implementing RADEC and PBL learning models can help reduce the impact of limitations on implementation. More skillful teachers will be able to manage time and materials more effectively and provide guidance that suits students' needs.
5. Long-term Evaluation

Research with long-term evaluation can provide deeper insight into the impact of learning models on students' mathematical communication skills. For example, conducting a follow-up study several months after implementation to see the extent to which students retain the skills they have learned.

6. Improving Infrastructure Support and Learning Environment

   Improving supporting facilities, such as providing learning media and Learner Worksheets (LKPD) specifically designed to support both learning models, can also help students understand the material better

While the findings of this study are informative, they may not fully generalize to all educational contexts due to the limitations mentioned above. For future research, a more comprehensive study design could include a larger, more diverse sample and a longer intervention period. Additionally, conducting studies across various schools, regions, and demographic groups would enhance the external validity and generalizability of the results. To improve the rigor of future studies, researchers could also consider using mixed methods (quantitative and qualitative) to provide a deeper understanding of how these learning models affect students' mathematical communication skills in real-world educational settings.

4. CONCLUSION

In the experimental class using the RADEC model, the N-Gain scores ranged from 0.10 (10%) to 1.00 (100%), with an average of 0.66 (65.75%), indicating an increase in students' mathematical communication skills at the medium level category. In the control class using the PBL model, scores ranged from 0.06 (6.25%) to 0.65 (65%), with an average of 0.30 (30%), indicating a low improvement in skills.

The RADEC model was shown to be more effective in improving students' mathematical communication skills, as indicated by the higher average N-Gain score. This effectiveness can be explained by the structured approach in the RADEC model, which includes stages that actively engage students in reading, answering, discussing, explaining, and creating, which is in line with cognitive theories that emphasize active learning and student engagement. In contrast, while the PBL model is strong in developing problem-solving skills, it does not provide enough focus on improving mathematical communication.

The findings suggest that educators who want to improve students' mathematical communication skills should consider implementing the RADEC model. This highlights the importance of early preparation of students by reading and answering essential questions at home prior to school learning as well as a structured and interactive learning environment that encourages discussion and reflection. Educators can use these insights to refine their teaching strategies and inform professional development programs, particularly in helping teachers integrate active learning models that promote communication skills.

This study has several limitations, including its restriction to a single mathematical topic ratio and the relatively small sample size drawn from only one school. Therefore, the findings may not be broadly generalizable. Future research is encouraged to investigate the application of the RADEC instructional model across a wider range of mathematical topics, various grade levels, and in different school contexts to enhance its external validity. Moreover, subsequent studies could explore the long-term effects of such instructional approaches on students’ mathematical communication abilities and assess the role of teacher professional development in supporting effective implementation.

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