Problem-based learning innovation through realism and culture: Impact on mathematical problem solving and self-efficacy in primary school students

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Abstract

Background: Elementary school students in Aceh Tamiang often struggle with problem-solving which negatively impacts their confidence. To address this issue, a new teaching approach called PBL-Reathnomath was developed, combining problem-based learning with real-world math examples and cultural references.

Aim: This study aimed to determine the effectiveness of the PBL-Reathnomath model at improving students' problem-solving skills and self-efficacy.

Method: A study was conducted involving randomly selecting participants and dividing them into two groups. One group learned using the new PBL-Reathnomath model while the other group learned using traditional methods. Data were collected through tests and surveys and the results were analyzed using statistical methods.

Results: The findings showed that the PBL-Reathnomath model significantly improved both the problem-solving abilities and self-efficacy of the students. The group that used this new model performed better on average than the group that used traditional methods. Further analysis confirmed that the PBL-Reathnomath model simultaneously affected problem-solving and self-efficacy, explaining a substantial portion of the variation in these outcomes.

Conclusion: While the effect size was smaller compared to conventional learning, the study concluded that PBL-Reathnomath is a valuable and specialized approach for improving problem-solving skills and boosting self-confidence among elementary school students.

INTRODUCTION

Indonesia, Education holds a crucial role in determining a nation's caliber, serving as a fundamental element for success in the modern era. In anticipation of these challenges, a curriculum has been devised to prompt students in honing their mathematical thought processes through engaging, imaginative, and adept activities, thus rendering mathematics education more profound (Milaturrahmah et al., 2017). This curriculum, known as the 2013 curriculum, aims to equip students with the skills to become industrious, inventive, innovative, steadfast, efficient, and contributing members of society (Rizkianto & Santosa, 2022; Wahyuningsih, 2019). However, a disparity exists between aspirations and reality. The outcomes of the 2018 PISA assessment underscore this, revealing Indonesia's placement at 72nd out of 78 countries and a score of 379, falling below the global average of 489. This underperformance is attributed

to students' lack of exposure to problem-solving tasks that require advanced cognitive skills, leaving them inadequately prepared for assessments like PISA (Sarah et al., 2021).

To address this, students need to be regularly exposed to problem-solving tasks, making mathematics a vital part of everyday life, as most human problems involve mathematical applications (Hafidzah et al., 2021; Mushlihuddin et al., 2018). Problem-solving in mathematics education is crucial as it helps students select, analyze, and investigate relevant information (Sundayana & Parani, 2023; Yayuk & Husamah, 2020). This approach fosters intellectual satisfaction, enhances students' intellectual potential, and teaches them how to make discoveries through exploration. Consequently, students develop logical and creative reasoning skills, collaborate with peers, and build self-efficacy to tackle real-life mathematical problems (Rahman & Nasryah, 2021).

Despite these efforts, Indonesian students' problem-solving skills remain below international standards. The 2015 TIMSS survey revealed that while the international average score was 500, Indonesian students scored 397, indicating relatively low problem-solving abilities (Afriansyah, 2017; Widjajanti, 2023). This deficiency is evident at the elementary level, affecting students' confidence in learning mathematics. Low self-efficacy leads to apathy, resignation, and helplessness, while high self-efficacy fosters commitment and resilience in problem-solving (Balivada, 2020; Bowen, 2019; Jackson, 2019; Gecas, 1989; Rodkjaer et al., 2021).

To improve mathematical problem-solving skills, innovative teaching methods tailored to students' needs are essential. Traditional classrooms often result in boredom, preventing students from exploring real-life problems and negatively impacting their self-efficacy in mathematics. Effective learning involves connecting subject matter to students' life experiences, encouraging them to formulate and solve problems under teacher guidance. This approach aligns with Haryanto & Arty's (2019) research, emphasizing the importance of developing students' thinking skills and connecting their knowledge with real-life situations.

Current classroom learning often lacks emphasis on reinforcing concepts and making the teaching process meaningful, leading students to forget initial concepts and struggle with new ones. This difficulty harms students' self-efficacy and mathematical thinking skills. Basic concepts are foundational in mathematics, with each concept building on another. Therefore, students should be given more opportunities to explore mathematical concepts independently (Hafiz & Dahlan, 2017). Various learning models, such as problem-based learning, project-based learning, ethnomathematics, and realistic mathematics education, are crucial for successful learning. These models can be combined into the PBL-Reathnomath model to enhance mathematical thinking and student collaboration, thereby increasing self-efficacy (Rahman et al., 2020).

The PBL-Reathnomath model, developed by Rahman et al. in 2020, is based on contextual problems and involves students' cultural environment. Ethnomathematics, rooted in Vygotsky's theory, suggests that individuals understand mathematics better when exposed to familiar cultural contexts, making learning more meaningful. This model aligns with students' mental functions and environmental involvement, supported by Polya's theory that learning is a thinking activity and a meaningful process embedded in memory. The Realistic Mathematics Education (RME) approach, suitable for primary school students in the concrete operational stage, is also integrated into this model.

In this model, students engage in problem-solving at the start of the learning process through the scientific method, making learning meaningful by solving real-life problems in their cultural context. The teacher's role is to facilitate and guide the reconstruction of mathematical ideas, allowing students to discover solutions through their efforts. This approach not only improves problem-solving skills but also enhances self-efficacy. The PBL-Reathnomath model combines problem-based learning with realistic characteristics and local culture, allowing students to learn mathematics while recognizing local cultural artifacts (Rahman et al., 2020).

Several studies related to the application of PBL models have been conducted. PBL in primary school learning can also help students develop collaboration, communication and problem-solving skills (Hotimah, 2020; Risandy et al., 2023). Through group work and interaction with classmates, students can learn to work together, listen to and respect the opinions of others, and find solutions together (Wardani, 2023; Sari & Kristin, 2020). PBL also provides opportunities for students to develop their creativity (Rahmadani, 2019). In the process of enquiry and exploration, students are exposed to situations that require creative thinking in finding solutions or generating new ideas (Samura, 2019; Sukriyatun et al., 2023). This can stimulate the development of students' creative potential and increase their confidence in conveying their ideas (Mukhlis & Herianingtyas, 2021). The problem-based learning model will be supported by the RME approach in order to bring out real mathematics learning and require students to construct knowledge with their own abilities through activities carried out in learning activities (Ningrum et al., 2024). The role of the teacher must change from a validator to someone who acts as a mentor who values each student's contribution. Mathematical concepts emerge from the mathematisation process, which starts from context-link solutions, students slowly develop mathematical tools and understanding to a more formal level, and then also include elements of ethnomathematics (mathematics in a cultural perspective) in the learning process so that students can directly benefit from learning mathematics. The method of embedding ethnomathematics-based mathematics learning in the classroom is in the form of indicators that students believe in and preserve their culture (Safitri et al., 2023). In teaching and learning activities with ethnomathematics-based learning, teachers introduce, connect, and utilise the culture that exists in the environment around us as the origin of learning, facilities, and even tools related to the subject matter of the components (Nisa et al., 2023). However, there has never been a study that combines the PBL model with RME and ethnomathematics, so researchers combine all the advantages that exist in PBL, RME and Ethnomathematics as the latest innovation in learning mathematics called PBL-Reathnomath (PBL based on RME and Ethnomathematics) which can train problem solving skills and increase self-efficacy of elementary school students.

METHODS

Research Design:

This study employs a quantitative research approach to investigate the relationship between the independent and dependent variables. A quasi-experimental design, specifically a posttest-only control group design, is used to examine the effect of a particular intervention on a specific variable within a controlled setting. As shown in Figure 1, this design involves comparing outcomes between an experimental group receiving the intervention and a control group that does not, with both groups undergoing assessment only after the intervention has been applied. While this approach offers some control over variables, it does not fully account for external factors that might affect the experiment's results (Aloe et al., 2017; Flannelly et al., 2018; Sackett & Mullen, 1993).

Group	Treatment	Result
Experiment	X	O_1
Control	-	O_2

Figure 1. Posttest Only Control Group Design

Note:

X = The treatment is the implementation of learning by using PBL-Reathnomath

O_1 = Posttest scores in the experimental group

O_2 = Posttest scores in the control group.

In this study, one group of students, referred to as the experimental group, received instruction based on the PBL-Reathnomath model, while another group, known as the control group, received standard instruction. The researcher aimed to control external factors that could influence the dependent variable but acknowledged the difficulty of doing so completely. Both groups were drawn from the same population of Class IV students at SD Tanjung Mulia, ensuring that they shared relevant characteristics for the study. Sampling aimed to ensure the sample accurately represented the population. Simple random sampling was employed, meaning sample members were randomly selected from the population without considering the existing strata within it.

The researcher carried out initial observations to collect data on learning requirements, student attributes, materials, concepts, and learning goals, shaping the design of instruments for data collection. The study comprised two classes: the experimental class, where instruction followed the PBL-Reathnomath model, and the control class, which received conventional instruction. Upon completion of the learning period, students underwent a formative assessment, or posttest, to gauge the progress in abilities between those instructed with PBL-Reathnomath and those with conventional methods. The research process flow is depicted in the accompanying figure.

Participants:

Random sampling was employed in this study to ensure that every Class IV student at SDN Tanjung Mulia had an equal chance of being selected for either the experimental or control group (Stratton, 2019). Through simple random sampling, Class IV-C, consisting of 35 students, was designated as the experimental group, while Class IV-E, also with 35 students, was designated as the control group.

Instruments:

In this study, the instruments utilized comprised tests and questionnaires. The test aimed to evaluate students' comprehension of geometric concepts by presenting problem-solving questions relevant to geometry. This test, validated by experts, was deemed highly valid for assessing students' problem-solving skills. It was administered post-treatment to gauge students' geometry problem-solving abilities and discern discrepancies between the two groups. Furthermore, a self-efficacy questionnaire was employed to ascertain students' confidence levels in learning mathematics, particularly in geometry.
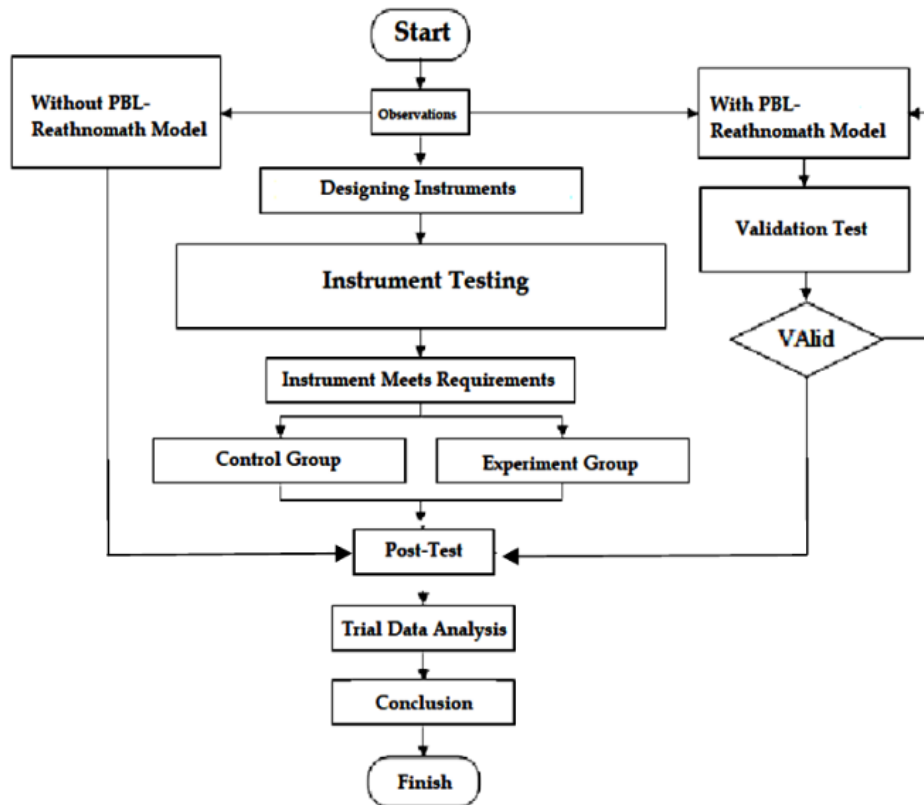
Figure 2. Research Flow

Data Analysis:

The primary data in this study were gathered through problem-solving ability tests and self-efficacy questionnaires administered to all participants. Standard quantitative research methods were used to analyze the collected data. The analysis process involved: 1) organizing data by variables and respondent groups, 2) summarizing the data for all respondents in tables by variable, 3) presenting the data for each variable under investigation, and 4) performing calculations to test the hypotheses. Multivariate Analysis of Variance (MANOVA) was employed as the main statistical tool for data analysis.

Basic Assumptions Test

Before hypothesis testing with MANOVA, several requirements must be met:

1. Test of Variance Homogeneity

   This test checks if sample data groups come from populations with equal variances, performed using SPSS 22. The hypotheses are:

- H_0 : Variance is the same in each group (homogeneous).
- H_a : Variance is not the same in each group (non-homogeneous).

   The "Sig." value in the output indicates the significance level. If the significance is greater than $\alpha = 0.05$, the variances are homogeneous. If less, the data is non-homogeneous.

2. Box'S M Test

   Box's M test assesses the equality of variance-covariance matrices of the dependent variables required for MANOVA.

Multivariate Test (MANOVA)

MANOVA was used to test the influence of PBL-Reathnomath on problem-solving abilities and self-efficacy of grade IV students at SDN Tanjung Mulia. The hypotheses are:

- H_0 : There is no influence of PBL-Reathnomath on the problem-solving abilities and self-efficacy of grade IV students in SDN Tanjung Mulia.
- H_a : There is an influence of PBL-Reathnomath on the problem-solving abilities and self-efficacy of grade IV students in SDN Tanjung Mulia.

According to the hypothesis, the criteria used to determine the assumption are as follows: if the Sig. Value in the table is less than 0.05, then H0 is rejected; conversely, if the Sig. value is greater than 0.05, then H0 is accepted.

Determinant Coefficient

The coefficient of determination (R^2) is used to assess the extent to which the PBL-Reathnomath model explains the variability observed in the dependent variables, namely problem-solving abilities and self-efficacy. R^2 values fall within the range of zero to one ($0 < R^2 < 1$). A lower R^2 value indicates that the independent variables have limited power in explaining the variation, while a value closer to one suggests that the independent variables provide nearly all the necessary information to predict the variation in the dependent variable.

$$KD = r^2 \times 100\%$$

Explanation:

KD = Coefficient of Determination

R = Correlation coefficient

RESULTS AND DISCUSSION

Result

Based on the conducted research, all the data obtained will be further analyzed to test the predetermined hypotheses. The data to be analyzed in this study consist of the results from mathematical problem-solving tests and self-efficacy questionnaires of both sample groups. Prior to analyzing the data, the researcher will use prerequisite tests to ensure that the estimation basis used later can employ MANOVA testing. Within the prerequisite tests, there are two tests, namely the homogeneity test and Box's M test. Lastly, the hypotheses will be tested using MANOVA to determine the influence of PBL-Reathnomath on mathematical problem-solving and student self-efficacy.

Table 1. Descriptive Statistics

	Learning Model	Mean	Std. Deviation	N
Problem Solving (Y1)	PBL-Reathnomath	70.5714	17.06783	35
	Conventional	60.2187	12.83829	32
	Total	65.6269	15.95717	67
Self-Efficacy (Y2)	PBL-Reathnomath	80.7143	9.46067	35
	Conventional	70.5000	13.04830	32
	Total	75.8358	12.34921	67

The hypothesis testing results for the problem-solving and self-efficacy of grade IV-C students at SDN Tanjung Mulia, who formed the experimental group with 35 respondents, showed an average problem-solving test score of 70.5714 and an average self-efficacy score of 80.7143. In contrast, the grade IV-E students at SDN Tanjung Mulia, comprising the control group with 32 respondents, had an average problem-solving test score of 60.2187 and an

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average self-efficacy score of 70.5. These results indicate that students taught using the PBL-Reathnomath method outperformed those who received conventional teaching methods in both problem-solving and self-efficacy.

Basic Assumptions Test

Before conducting the hypothesis test using MANOVA, several requirements must be met. These requirements are:

1. Test for Homogeneity of Variance

This test aims to ascertain whether the data acquired from both the experimental and control groups exhibit similar or disparate variances. Utilizing data from tests conducted in both groups, the homogeneity test compares variances. If the significance value is ≥ 0.05, it suggests equivalent variances, whereas if the significance value is ≤ 0.05, it implies differing variances. The homogeneity test in this study was executed using SPSS 22, with a specific focus on the Levene test results, detailed in the subsequent table.

Table 2. Levene's Test of Equality of Error Variances

	F	df1	df2	Sig.
Problem Solving (Y1)	2.425	1	65	.124
Self-Efficacy (Y2)	2.669	1	65	.107
Tests the null hypothesis that the error variance of the dependent variable is equal across groups.				
a. Design: Intercept + Learning_Model				

Hipotesis:

* H_0 : Variations within each group are the same (homogeneous).
* H_a : Variations within each group are not the same (non-homogeneous)

The outcomes of Levene's test reveal that the significance value for problem-solving is 0.124, and for Self-Efficacy, it is 0.107. With a significance level of 0.05 established, both problem-solving and self-efficacy values exceed 0.05, indicating acceptance of H0, denoting homogeneous variance. Consequently, the MANOVA analysis can proceed.

2. Test of Homogeneity of Variance

This test examines the degree of variance between two related variables. A significance level of 0.05 or higher suggests consistent distribution, while a level below 0.05 implies inconsistency. MANOVA analysis necessitates equality in the variance/covariance matrix of the dependent variables. Box's M test assesses this homogeneity. A significant Box's M value leads to rejecting the null hypothesis (H0) of equal variance/covariance matrix, hindering further MANOVA analysis.Results of Box's M test, conducted using SPSS 2', are detailed in the following table.

Table 3. Box's Test of Equality of Covariance Matrices

Box's M	6.020
F	1.939
df1	3
df2	1038839.269
Sig.	.121
Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.	
A. Design: Intercept + Learning_Model	

Hypothesis:

- H_0 : The variance/covariance matrix of the dependent variables is uniform..
- H_a : The variance/covariance matrix of the dependent variables is not uniform.

The Box's Test of Equality of Covariance matrices reveals a significance value of 0. 121. Given the research significance level of Sig. > 0.05, the obtained value surpasses 0.05. Consequently, the null hypothesis (H0) is accepted, indicating that the variance/covariance matrix of the dependent variables is uniform. This confirmation permits the MANOVA analysis to proceed.

Multivariate Test (MANOVA)

After both hypothesis testing requirements are met, the MANOVA hypothesis test is conducted. The MANOVA test examines whether there are differences in multiple dependent variables among several groups.

Table 4. Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Problem Solving (Y1)	1791.631[a]	1	1791.631	7.756	.007
	Self-Efficacy (Y2)	1744.051[b]	1	1744.051	13.624	.000
Intercept	Problem Solving (Y1)	285952.228	1	285952.228	1237.968	.000
	Self-Efficacy (Y2)	382233.603	1	382233.603	2985.790	.000
Learning_Model	Problem Solving (Y1)	1791.631	1	1791.631	7.756	.007
	Self-Efficacy (Y2)	1744.051	1	1744.051	13.624	.000
Error	Problem Solving (Y1)	15014.040	65	230.985		
	Self-Efficacy (Y2)	8321.143	65	128.018		
Total	Problem Solving (Y1)	305367.000	67			
	Self-Efficacy (Y2)	395387.000	67			
Corrected Total	Problem Solving (Y1)	16805.672	66			
	Self-Efficacy (Y2)	10065.194	66			
a. R Squared = .407 (Adjusted R Squared = .393)						
b. R Squared = .473 (Adjusted R Squared = .461)						

Hypothesis Testing:

- H_0: There is no influence of PBL-Reathnomath on mathematical problem-solving.
- H_1: There is a significant influence of PBL-Reathnomath on mathematical problem-solving.
- H_0: There is no influence of PBL-Reathnomath on self-efficacy.
- H_1: There is a significant influence of PBL-Reathnomath on self-efficacy.

According to the Tests of Between-Subjects Effects table:

1. The comparison between the experimental and control groups regarding problem-solving scores resulted in an F value of 7.756 with a significance level of 0.007 < 0.05. Therefore, the null hypothesis (H0) is rejected, suggesting a significant effect of PBL-Reathnomath on mathematical problem-solving, with an effect size of 40.7%.
2. The comparison between the experimental and control groups regarding student self-efficacy scores yielded an F value of 13.624 with a significance level of 0.000 (less than

0.05). Consequently, the null hypothesis (H0) is rejected, suggesting a significant influence of PBL-Reathnomath on self-efficacy, with an effect size of 47.1%

To further assess the impact of PBL-Reathnomath on both mathematical problem-solving and student self-efficacy, Pillae Trace, Wilk Lambda, Hotelling Trace, and Roy's Largest Root analyses were conducted. The detailed results of these analyses are provided below.

Table 5. Multivariate Tests

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.983	1854.872[b]	2.000	64.000	.000
	Wilks' Lambda	.017	1854.872[b]	2.000	64.000	.000
	Hotelling's Trace	57.965	1854.872[b]	2.000	64.000	.000
	Roy's Largest Root	57.965	1854.872[b]	2.000	64.000	.000
Learning_Model	Pillai's Trace	.225	9.314[b]	2.000	64.000	.000
	Wilks' Lambda	.775	9.314[b]	2.000	64.000	.000
	Hotelling's Trace	.291	9.314[b]	2.000	64.000	.000
	Roy's Largest Root	.291	9.314[b]	2.000	64.000	.000

a. Design: Intercept + Learning_Model
b. Exact statistic

Hypothesis Test:
- H_0 : The PBL-Reathnomath approach has no impact on mathematical problem-solving and student self-efficacy.
- H_a : The PBL-Reathnomath approach influences mathematical problem-solving and student self-efficacy.

The analysis demonstrates that the F values for Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root are all statistically significant, with a significance level of 0.000, which is below 0.05. This indicates the significance of these measures. Consequently, the null hypothesis (H0) is rejected, and the alternative hypothesis (Ha) is accepted, suggesting that the PBL-Reathnomath approach does impact both mathematical problem-solving and student self-efficacy.

Discussion

The analysis reveals a substantial effect of the PBL-Reathnomath model compared to conventional teaching methods on the mathematics learning outcomes related to plane figures for Grade IV students at SDN Tanjung Mulia. This effect is underscored by the significant values obtained in the Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root analyses, all of which were less than 0.05, specifically 0.000. These findings strongly suggest that PBL-Reathnomath significantly enhances both the problem-solving abilities and self-efficacy of students in this study.

This research result shows that the PBL-Reathnomath model is superior to the conventional model, supported by descriptive test and questionnaire data, as well as findings during the research process in the experimental class. Implementing the PBL-Reathnomath model helps students understand the concept of plane geometry in the context of everyday life and its general usefulness for humans. Students can effectively learn the concept of plane geometry by integrating Acehnese culture into their educational activities. This approach aligns

with critical trends in mathematics education that aim to combat ignorance and oppression (Williams, 2011). Visual representations play a crucial role in structuring geometry activities in the classroom and can aid students in visualizing mathematical objects (David & Tomaz, 2011). Additionally, the use of cultural artifacts, such as proverbs, can serve as valuable educational media by imparting linguistic knowledge and positive cultural values (Mansyur & Suherman, 2020). In the context of Acehnese culture, farming-related proverbs embody essential cultural values like trustworthiness, patience, and diligence (Ibrahim & Usman, 2021). As Vygotsky (1997) stated, higher mental functions can be achieved through social interaction involving facts and symbols. Facts and symbols from the cultural environment influence individual understanding.

Furthermore, the PBL-Reathnomath model also applies constructed and self-developed learning by students, as this model makes students experts in the field. Solving problems does not have to be unique or the same for everyone. People can find or use their methods if they diligently work on the problems. By comparing different problem-solving approaches, the most appropriate solution can be obtained, aligning with the goal of the problem-solving process.

The PBL-Reathnomath model fosters active student engagement, facilitates meaningful learning experiences, and encourages the practical application of mathematical concepts in real-world scenarios. The coefficient of determination (R^2) indicates the extent of influence the PBL-Reathnomath model exerts on students' problem-solving skills and self-efficacy. With R^2 values of 40.7% for problem-solving and 47.3% for self-efficacy, the model demonstrates a substantial impact on both aspects of student learning.

Implication

The implications of this research, particularly in mathematics education, are as follows:

1. Impact on Problem-Solving Ability: The PBL-Reathnomath model significantly enhances students' problem-solving abilities in geometry, with a large effect size of 40.7%. This suggests that the PBL-Reathnomath model can be recommended over conventional learning methods that primarily rely on group discussions and lectures.

2. Impact on Self-Efficacy: The PBL-Reathnomath model positively affects students' self-efficacy, with a substantial effect size of 47.3%. This indicates that the model boosts students' confidence in tackling mathematical problems, particularly in geometry. These findings underscore the importance of self-efficacy in mathematics education, demonstrating that it is influenced by students' problem-solving capabilities and their confidence, which can be nurtured through contextual and relatable problem-solving exercises.

Limitation and Suggestion for Further Research

This research has certain limitations and weaknesses. Primarily, the study's sample size was small, involving only 35 fourth-grade students from each class at SDN Tanjung Mulia, Aceh Tamiang. Moreover, the conclusion solely focused on the extent of the PBL-Reathnomath Model's influence without taking into account other variables that might have impacted the research process. Additionally, the study was limited to the topic of geometry, specifically calculating the area and perimeter of plane figures. To improve upon these limitations, future research could involve a larger and more diverse sample of students from different schools,

explore a wider range of mathematical topics beyond geometry, and consider including other influential variables in the research design.

CONCLUSIONS

The PBL-Reathnomath model, an innovative amalgamation of Problem-Based Learning (PBL), a Realistic Approach, and Ethnomathematics, effectively enhances students' problem-solving skills and self-efficacy in geometry. Tested in a fourth-grade class at SDN Tanjung Mulia, the model showcased a significant impact on problem-solving abilities (40.7%) and self-efficacy (47.3%). Despite a moderate effect size, it outperforms conventional methods. The PBL-Reathnomath model serves as a valuable reference for educators, advocating for a more contextual, collaborative, real-world, and relatable approach to teaching geometry, thus improving problem-solving skills and elevating student self-efficacy.

ACKNOWLEDGMENT

AUTHOR CONTRIBUTIONS STATEMENT

This research took place at SDN Tanjung Mulia, Aceh Tamiang. AA led the implementation of the PBL-Reathnomath Model in both the experimental and control groups, while RM assisted with managing research equipment and school administration. NU and CR validated all supporting instruments, and AA conducted the data calculation and analysis. Hypothesis testing was performed by CR and HZ.

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