

The Effect of Anxiety and Self-Efficacy on Mathematical Reasoning through Problem-Based Learning Models in Elementary School Students

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Abstract: This study aims to analyze the predictive power of mathematical anxiety and self-efficacy on students' mathematical reasoning skills after the application of the problem-based learning model (PBL), as well as the improvement of mathematical reasoning skills of grade V students of SD Negeri 70 Ambon after the implementation of the problem-based learning model (PBL). This study used a quantitative approach with a pre-experimental one-group pretest-posttest design. The research sample consisted of 30 students in class V, selected using purposive sampling techniques. Data were collected through mathematical reasoning ability tests, mathematical anxiety questionnaires, and self-efficacy questionnaires. Data were analyzed using descriptive statistics, prerequisite test analysis, multiple linear regression, and N-Gain analysis. The results showed that mathematics anxiety had a negative and significant predictive effect on students' mathematical reasoning ability after the application of the problem-based learning model (PBL), with a significance value of 0.004. Meanwhile, self-efficacy has a positive and significant predictive power on students' mathematical reasoning ability after the application of the problem-based learning model (PBL), with a significance value of 0.000. Simultaneously, math anxiety and self-efficacy had a significant predictive power on students' mathematical reasoning ability, with a significance value of 0.000. In addition, the N-Gain analysis showed an increase in students' mathematical reasoning skills after applying the problem-based learning model (PBL), with an average N-Gain of 0.7117, which falls in the high category. "This study shows that psychological factors in the form of mathematical anxiety and self-efficacy have an important role in explaining students' mathematical reasoning abilities after the application of the problem-based learning model. In addition, students' mathematical reasoning abilities showed improvement after participating in problem-based learning (PBL).

Keywords: mathematical reasoning ability, mathematical anxiety, self-efficacy, problem-based learning.

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■ INTRODUCTION

Education plays an important role in improving the quality of human resources, including spirituality, intellect, and the skills needed for daily activities (Sopiah et al., 2020). Through education, students are encouraged to develop their potential to become critical, creative, innovative, and skilled individuals (Fauziah et al., 2021). In this context, mathematics plays a strategic role because it not only serves as a basic

science but also as a means to train logical, analytical, systematic, and critical thinking skills in solving various problems. Therefore, mathematics learning needs to be designed to develop high-level thinking skills that can support students' success when facing life challenges and scientific development.

According to NCTM, mathematics learning includes five main skills, namely problem-solving, reasoning, communication, connection, and

representation (Pramuswara & Haerudin, 2022). A high-level aspect of thinking that needs to be developed in mathematics learning is mathematical reasoning skills. This skill helps a person think logically and critically so they can understand problems, draw conclusions, and make the right decisions in daily life (Putri et al., 2019). Given the importance of these skills, teachers need to create a learning space that gives students opportunities to actively engage in mathematical activities that encourage them to explore, develop, and discuss various mathematical ideas (Mahmud & Mohd Drus, 2023). In this context, strong mathematical reasoning skills are reflected in students' ability to construct logical arguments, choose appropriate solution strategies, and present rational reasons for the results obtained (Afifah et al., 2024).

However, Indonesian students' mathematical achievement remains relatively low. This is reflected in the 2022 PISA results, which ranked Indonesia 69th out of 81 countries in mathematics (Auliya et al., 2025). This achievement proves that students' ability to use mathematical models to dissect, reason, and solve contextual problems must be improved. This situation shows that the mathematics teaching system in schools has not been running optimally to improve students' mathematical reasoning skills (Sartika et al., 2024).

This phenomenon was also found at SD Negeri 70 Ambon based on the results of initial observations made by researchers. During mathematics learning, students seem less active in participating in learning activities and still have difficulty solving problems given by the teacher. Learning is also still teacher-dominated, so students' opportunities to express opinions, discuss, and develop ways of thinking to solve problems are not optimal. This suggests that the learning process has not fully provided space for students to develop their mathematical reasoning skills.

One psychological factor thought to affect mathematical reasoning is mathematical anxiety. In general, Math anxiety is a sense of tension or discomfort that arises when a person faces a situation related to numbers and mathematics (Gashaj et al., 2023). This condition is characterized not only by feelings of nervousness, tension, and worry, but also by negative thoughts about one's abilities and uncomfortable physical responses when facing math (Henschel & Roick, 2020). High math anxiety can form a negative cycle that has the potential to hinder students' learning and achievement processes (El-Far et al., 2024). In the learning process, such anxiety can reduce students' ability to maintain focus and manage the information needed to complete math tasks (Dowker et al., 2019). In line with Attention Control Theory, anxiety can interfere with concentration and divert attentional resources from the task at hand, making thinking and task completion less optimal (Eysenck et al., 2007).

In addition to math anxiety, another psychological factor that affects mathematical reasoning skills is self-efficacy, namely a person's belief that he can act to achieve the desired goal (Bandura, 1986). These beliefs can be formed and developed through students' success in completing academic tasks, which is an important factor in strengthening self-efficacy (Basileo et al., 2024). In the learning process, self-efficacy plays an important role because it can affect students' motivation, way of thinking, and behavior when facing learning tasks and challenges (Pintrich & Schunk, 2022). Confidence in one's abilities can increase motivation to learn and encourage student involvement in the learning process (Prifti, 2022). High self-efficacy makes students more confident in facing the demands of learning, so they tend to show better performance, more positive attitudes, and more optimal academic results (Alhadabi & Karpinski, 2020). On the other hand, individuals with low self-efficacy tend to have less appreciation for their abilities and

have a pessimistic view of their ability to achieve goals and develop their potential (Bandura, 1997).

In addition to internal factors, external factors in the learning process also influence mathematical reasoning skills, including the learning model used. Problem-based learning (PBL) is student-centered and encourages active involvement in critical thinking, problem-solving, and decision-making (Tursynkulova et al., 2023). Through this process, PBL not only encourages the development of critical thinking and problem-solving skills, but also helps students prepare themselves to face real-world situations (Ceker & Ozdamli, 2016). In line with this, PBL promotes active learning by encouraging students to think critically and use analytical reasoning to understand and solve problems relevant to daily life (Alashwal & Barham, 2025).

Various previous studies have shown a relationship between psychological aspects, learning models, and mathematical reasoning skills of students. Zhang et al. (2019) show a significant negative correlation between math anxiety and math performance, so students who experience higher math anxiety tend to show lower math performance. In contrast, Lestari et al. (2022) show that self-efficacy positively influences mathematical reasoning skills because students with high confidence in their abilities tend to be better able to face challenges in solving mathematical problems. Umaroh et al. (2020) also show that math anxiety and self-efficacy affect students' mathematical reasoning abilities simultaneously. Meanwhile, Safitri et al. (2025) show that implementing the PBL model helps improve students' mathematical thinking skills.

Although various studies have examined mathematical anxiety and self-efficacy as factors related to mathematical reasoning skills and applied problem-based learning models (PBL) as learning strategies, research integrating these two aspects is still limited. In particular, there is

still limited research that analyzes the predictive power of mathematical anxiety and self-efficacy on students' mathematical reasoning ability after the application of the problem-based learning model (PBL), as well as the improvement of students' mathematical reasoning skills after participating in problem-based learning (PBL). Previous research has generally examined math anxiety and self-efficacy separately or focused on applying PBL to improve learning outcomes. Therefore, this study applies problem-based learning (PBL) as a learning treatment and analyzes the predictive power of mathematical anxiety and self-efficacy on students' mathematical reasoning ability after the application of the problem-based learning model (PBL) and the improvement of students' mathematical reasoning skills after the implementation of the problem-based learning model (PBL).

Based on Bandura's Social Cognitive Theory, self-efficacy is a psychological factor related to students' confidence in their ability to complete math tasks. Meanwhile, math anxiety is related to emotional responses that can affect students when faced with math learning situations. Therefore, these two psychological factors are considered relevant to be studied in relation to students' mathematical reasoning skills.

In this study, the problem-based learning model (PBL) is used as a learning intervention for all students during the research process. This study analyzes the predictive power of mathematical anxiety and self-efficacy on students' mathematical reasoning abilities after the application of PBL, as well as the improvement of students' mathematical reasoning skills after participating in problem-based learning (PBL).

The novelty of this research lies in the integration of the problem-based learning model (PBL) as a learning treatment with the analysis of the predictive power of mathematical anxiety and

self-efficacy on students' mathematical reasoning skills after the application of the problem-based learning model (PBL), as well as the improvement of mathematical reasoning skills after participating in problem-based learning (PBL). Thus, this study provides a more comprehensive picture of students' mathematical reasoning abilities reviewed from psychological factors, especially mathematical anxiety and self-efficacy, after participating in problem-based learning (PBL).

This research is expected to contribute to mathematics education research, especially regarding the role of mathematics anxiety and self-efficacy in students' mathematical reasoning skills after applying the problem-based learning (PBL) model. In addition, the results of this research are expected to serve as a reference for teachers in designing mathematics learning that considers students' psychological aspects.

Based on this background, this study aims to analyze the predictive power of mathematical anxiety and self-efficacy on students' mathematical reasoning skills after the application of the problem-based learning model (PBL), as well as the improvement of students' mathematical reasoning skills on flat building materials in grade V of SD Negeri 70 Ambon.

For this purpose, the research questions are formulated as follows:

1. Do math anxiety and partial self-efficacy have predictive power on students' mathematical reasoning ability after the application of the problem-based learning model (PBL)?
2. Do math anxiety and self-efficacy simultaneously have predictive power on students' mathematical reasoning abilities after the application of the problem-based learning (PBL) model?
3. Is there an improvement in students' mathematical reasoning skills after the implementation of the problem-based learning model?

■ METHOD

This study was conducted from March 31, 2026, to April 15, 2026, at SD Negeri 70 Ambon, Sirimau District, Ambon City, Indonesia. The study population consisted of all fifth-grade students at SD Negeri 70 Ambon during the 2025/2026 school year. The research sample consisted of one class of 30 students, selected using purposive sampling. The sample was selected based on the initial observation of the mathematics learning process in fifth grade. These observations suggest that mathematics teaching tends to be teacher-centric, while student involvement in inquiry, discussion, and problem-solving activities is suboptimal. This situation supports the study's objectives: implementing a Problem-Based Learning (PBL) approach that allows students to actively discover concepts, solve problems, and build their understanding independently. The inclusion criteria included students registered as Grade V students in the 2025/2026 school year, participating in the entire research series (pretest, PBL learning, and posttest), and providing parents/guardians' consent to participate in the research. A total of 30 students met the inclusion criteria and participated in the entire research series. This research applied ethical principles of human subject protection by obtaining permits and approvals from relevant parties before conducting the research. The researcher obtained a research permit from the Faculty, approval from the principal as the party permitting research in the school environment, and informed consent from students' parents/guardians after explaining the objectives, procedures, and use of research data. Researchers also maintain the confidentiality of participants' identities and ensure that the data obtained is only used for academic purposes. The research participants' characteristics include selection criteria, inclusion criteria, average age, and initial academic characteristics in the form of average mathematical scores before the research, as presented in Table 1.

Table 1. Characteristics and demographics of research participants

Characteristics	Remarks	N	Value
Number of participants	Grade V students who are sampled	30	100%
Selection criteria	Classes were selected <i>purposively</i> based on the results of initial observation of mathematics learning	30	100%
Inclusion criteria	Students are registered as grade V students in the 2025/2026 school year, take part in the entire series of research (pretest, PBL learning, and posttest), and obtain parents/guardians' consent to participate in the research.	30	100%
Age	The average age of the students at the time of the study	30	10.63 years
Early academic characteristics	Average math score before the research	30	61.93

Research Design

This study used a quantitative approach with a pre-experimental, one-group pretest-posttest design. This design involved one research group without a control group. In the initial stage, students were given a *pretest to obtain preliminary data on mathematical reasoning skills, mathematical anxiety, and self-efficacy before receiving the treatment*. Furthermore, all students participated in learning using the problem-based learning (PBL) model as the treatment in this study. After the learning is complete, students are given a *posttest* to re-measure their mathematical reasoning skills, mathematical anxiety, and self-efficacy after applying the problem-based learning (PBL) model.

In this study, the problem-based learning model (PBL) serves as a treatment variable applied to all students during the learning process. The problem-based learning model (PBL) is not treated as an independent variable in regression analysis, but rather as a learning treatment given to all students. Multiple linear regression analysis was used to test the predictive power of mathematical anxiety and self-efficacy on students' mathematical reasoning abilities after the application of the problem-based learning model (PBL). In contrast, the improvement in students' mathematical reasoning ability was assessed using the N-Gain test based on *pretest and posttest*

results. The design of this study is presented in Table 2.

Table 2. One group pretest–posttest design

Pretest	Treatment	Posstest
O1	X	O2

Source: (Hartono, 2019)

Description:

O₁ : Pretest measurement, which includes mathematical reasoning skills, mathematical anxiety, and self-efficacy.

X : Treatment in the form of learning using a problem-based learning model (PBL) on flat building materials.

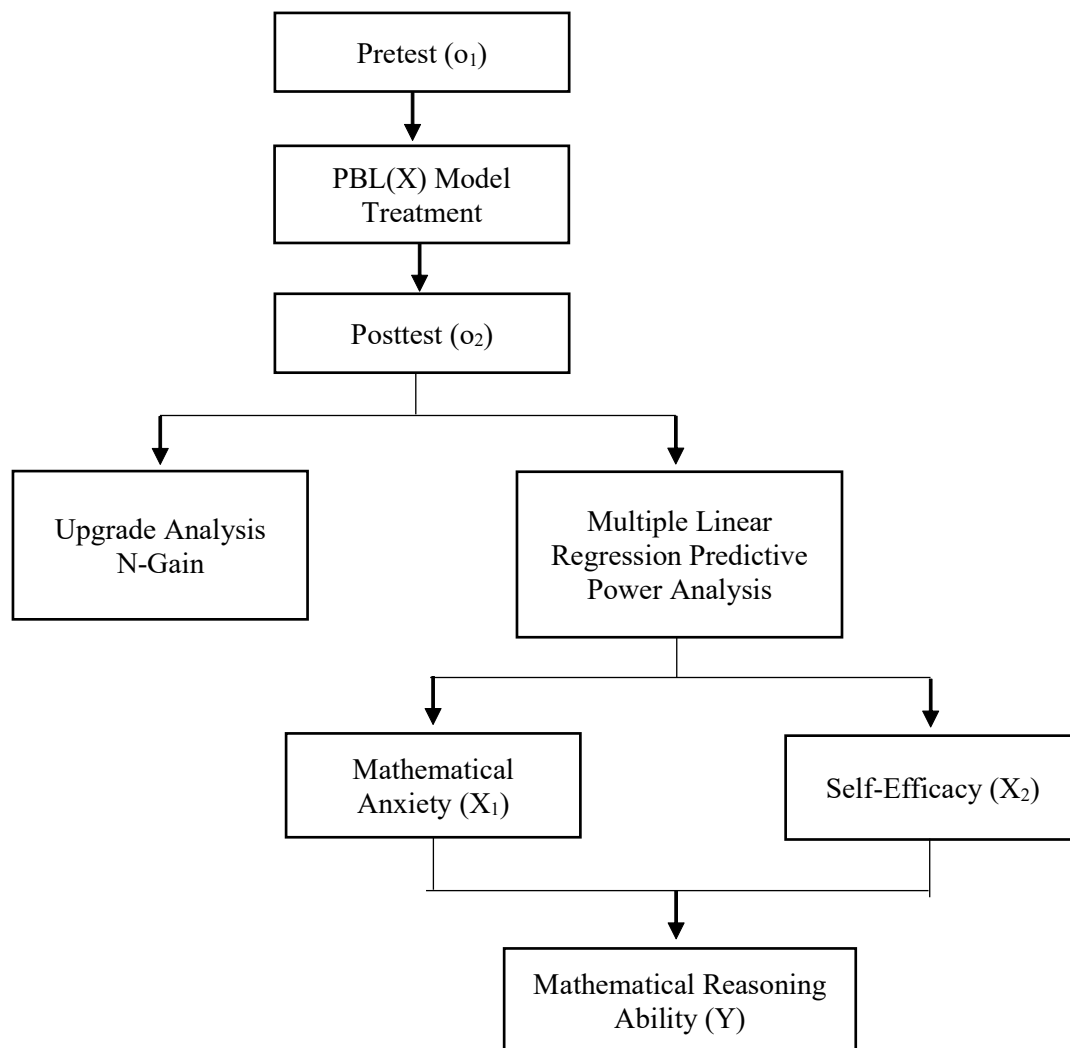
O₂ : Final measurement (*posttest*), which includes mathematical reasoning skills, mathematical anxiety, and self-efficacy.

Based on the prepared research design, a research framework was developed to describe the relationship between variables and clarify the position of the learning treatment in this study. This research framework aims to explain the role of each variable in the research and analysis process.

In this study, mathematical anxiety (X₁) and self-efficacy (X₂) served as independent variables to assess their predictive power on mathematical reasoning ability (Y). Meanwhile, the problem-based learning model (PBL) serves as a treatment

variable applied to all students during the learning process. The problem-based learning model (PBL) is not analyzed as an independent variable, but as a learning treatment that provides the research context. The improvement in students' mathematical reasoning skills after applying the

problem-based learning model (PBL) was analyzed using the N-Gain test. In contrast, the predictive power of mathematical anxiety and self-efficacy on mathematical reasoning skills was analyzed using multiple linear regression. The framework of this research is presented Figure 1



(Source: Sugiyono, 2013)

Figure 1. Research framework

Instruments

Data collection in this study was carried out through tests, questionnaires, and documentation. The test instrument consists of three descriptive questions used to measure students' mathematical reasoning skills. Questions were prepared based on indicators of mathematical reasoning ability,

which include the ability to make guesses, perform mathematical manipulations, compile evidence or give reasons for the solution, and draw conclusions (Asdarina & Ridha, 2020), while the assessment category of mathematical reasoning ability was determined based on the score interval developed by Asdarina & Ridha (2020).

In addition to the test, this study also used two questionnaires: the Mathematics Anxiety questionnaire and the self-efficacy questionnaire, each consisting of 16 statements on a four-point Likert scale. The *Mathematics Anxiety* Compiled based on indicators that include aspects of knowledge or understanding of mathematics, somatic, cognitive, and attitude (Vrasetya & Gunawan, 2024). Meanwhile, the self-efficacy questionnaire was developed based on the dimensions *Magnitude*, *General*, and *Strength* (Pratiwi & Imami, 2022). The questionnaire scores are then categorized using hypothetical averages and hypothetical deviation standards, as quoted in Utami et al. (2020).

Before use in the study, experts validated all instruments to assess the suitability of content, constructs, and language. Furthermore, the instrument was tested on 30 respondents to determine the validity and empirical reliability. The validity test was performed using Pearson's Product-Moment correlation by comparing each item value against the *r* table. At a significance level of 5% with 30 respondents ($df = 28$), the *r*-table value was 0.361. The instrument item is declared valid if the value of *r* is greater than the *r*-table ($r\text{-calculated} > r\text{-table}$). Meanwhile, reliability tests were performed using Cronbach's Alpha coefficient to measure the instrument's internal consistency. An instrument is declared reliable if it has a Cronbach's Alpha value greater than 0.70 (Soesana et al., 2023).

The validity test results show that all instruments meet the validity criteria. The *Mathematics Anxiety* questionnaire obtained a calculated *r* value ranging from 0.436–0.770; the self-efficacy questionnaire obtained a calculated *r* value ranging from 0.445–0.753; while the mathematical reasoning ability test instrument obtained a calculated *r* value ranging from 0.563–0.759. The overall *r*-value is greater than the table value (0.361), so all items are declared valid and suitable for use in the study.

The reliability test results showed that the *Mathematics Anxiety* questionnaire obtained a Cronbach's Alpha value of 0.899, the self-efficacy questionnaire obtained a Cronbach's Alpha value of 0.881, and the mathematical reasoning ability test instrument obtained a Cronbach's Alpha value of 0.798. The overall Cronbach's Alpha was above 0.70, so the three instruments had a good level of internal consistency and were declared reliable as data collection instruments in this study.

Data Analysis

The data analysis techniques in this study included descriptive statistical analysis and inferential statistics. Descriptive statistical analysis was used to describe the data characteristics of mathematical reasoning ability, mathematical anxiety, and student self-efficacy. Meanwhile, inferential statistical analysis was used to test the research hypothesis. Before the hypothesis test, the analysis prerequisites test was carried out, including the normality test, linearity test, heteroscedasticity test, and multicollinearity test, as requirements for multiple linear regression analysis. The normality test was determined based on the significance value of ≥ 0.05 , the linearity test based on the *Deviation from Linearity* value ≥ 0.05 , the heteroscedasticity test based on the significance value of ≥ 0.05 , and the multicollinearity test based on the *Tolerance* value > 0.10 and the *Variance Inflation Factor* (VIF) < 10 .

Hypothesis testing is carried out in several stages. The predictive power of mathematical anxiety and self-efficacy on students' mathematical reasoning ability after applying the problem-based learning model (PBL) was analyzed using multiple linear regression, with a *t*-test to determine partial predictive power and an *F*-test to determine simultaneous predictive power at a significance level of < 0.05 . Furthermore, the improvement in students'

mathematical reasoning skills after participating in learning using the problem-based learning model (PBL) was analyzed using the N-Gain test based on the pretest and posttest results.

■ RESULT AND DISCUSSION

Math Anxiety

This study measured mathematical anxiety using a questionnaire consisting of 16 statements. Based on descriptive statistical analysis, the average mathematics anxiety score of students in the posttest stage was lower than in the pretest stage. The average math anxiety score decreased from 49.67 in the pretest stage to 39.10 in the posttest stage. Based on the results of the categorization of mathematics anxiety scores, there was a change in the distribution of students'

mathematical anxiety levels between the pretest and posttest stages. In the pretest stage, as many as 21 students (70%) were in the high anxiety category, and 9 students (30%) were in the medium category, while there were no students in the low category. In the posttest stage, the number of students in the high anxiety category decreased to 2 students (7%). In comparison, the number of students in the medium category increased to 25 students (83%) and the low category to 3 students (10%). Descriptively, the results show that the distribution of students' math anxiety levels in the posttest stage tends to shift to a lower category than in the pretest stage. The distribution of mathematical anxiety categories by indicator can be seen in Figure 2.

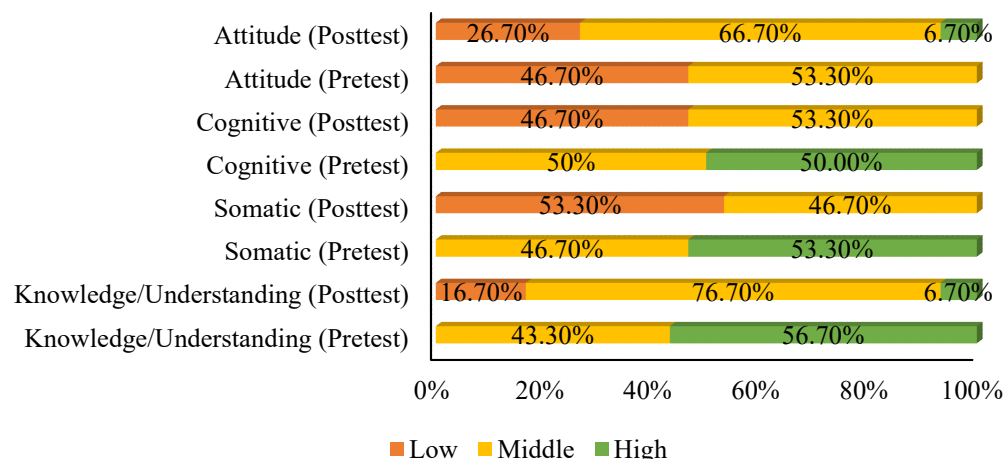


Figure 2. Distribution of mathematical anxiety categories by indicators

Figure 2 shows the distribution of students' math anxiety categories between the pretest and posttest. The proportion of students in the high anxiety category tends to decrease in the posttest. Based on four indicators, namely *Somatic*, *Attitude*, *Cognitive*, and *Knowledge/Understanding*, there was a decrease in the average score, with a different amount in each indicator. The largest decrease was in the *Somatic* indicator (0.742), followed by *Attitude* (0.733), *Cognitive* (0.558), and *Knowledge/Understanding* (0.489). Descriptively, the

Somatic indicator showed the greatest change among the indicators. This shows that aspects of the physical response to math anxiety, such as tension, nervousness, and discomfort when facing learning or math tasks, have the largest difference in average scores between pretest and posttest.

Self-Efficacy

Self-efficacy in this study was measured using a questionnaire consisting of 16 statements. Based on descriptive statistical analysis, the average student self-efficacy score at the posttest

stage was higher than at the pretest stage. The average self-efficacy score increased from 33.97 in the pretest stage to 47.30 in the posttest stage. Based on the score categorization results, the distribution of students' self-efficacy levels changed between the pretest and posttest stages. In the pretest stage, 19 students (63.3%) were in the low category, 8 students (26.7%) were in the medium category, and 3 students (10%) were in the high category. At the posttest stage, no

more students were found in the low category. The number of students in the medium category increased to 16 students (53.3%), while the number of students in the high category increased to 14 students (46.7%). Descriptively, the results show that the distribution of students' self-efficacy levels in the posttest stage tends to shift toward a higher category than in the pretest stage. The distribution of self-efficacy categories based on indicators can be seen in Figure 3.

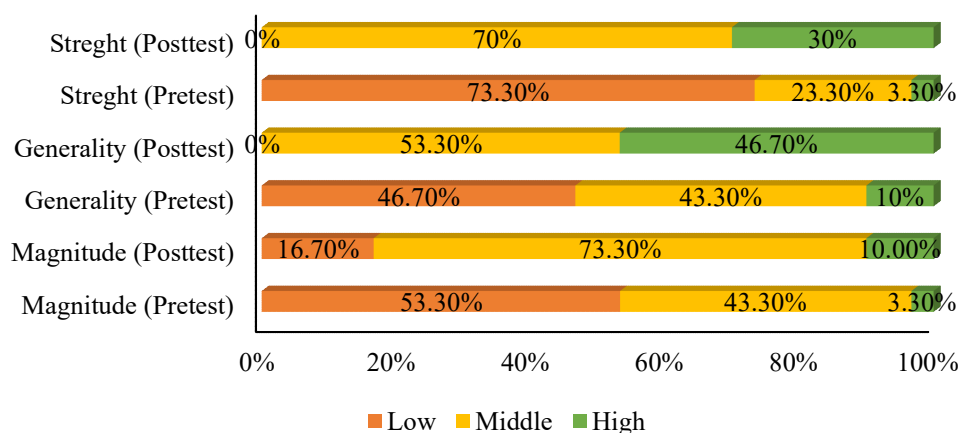


Figure 3. Percentage distribution of self-efficacy categories

Based on Figure 3, the distribution of student self-efficacy categories changed between the pre-test and post-test stages in three indicators: *Magnitude*, *Strength*, and *Generality*. In all three indicators, the proportion of students in the low category decreased, while the proportion in the medium and high categories increased in the post-test. In addition, the three indicators increased in terms of average value, namely *Magnitude* (0.733), *Strength* (0.790), and *Generality* (0.973). Descriptively, the *Generality* indicator showed the highest increase, followed by *Strength* and *Magnitude*. These results show a change in students' self-efficacy achievements between the pre-test and post-test stages.

Mathematical Reasoning Skills

Students' mathematical reasoning ability was measured using a descriptive test consisting

of three questions arranged according to mathematical reasoning indicators. The results showed a change in students' mathematical reasoning achievement after they received treatment in the form of a problem-based learning model (PBL). The average score of mathematical reasoning ability increased from 22.83 in the pre-test to 77.80 in the post-test. Based on the score categorization, all students (100%) were in the low category on the pre-test. After receiving PBL treatment, the category distribution changed: 18 students (60%) were in the high category, 10 students (33%) in the medium category, and 2 students (7%) in the low category. Thus, most students obtained higher post-test scores than pre-test scores. Visually, changes in the distribution of mathematical reasoning ability scores between pretest and posttest can be observed through the paired boxplot presented in Figure 4.

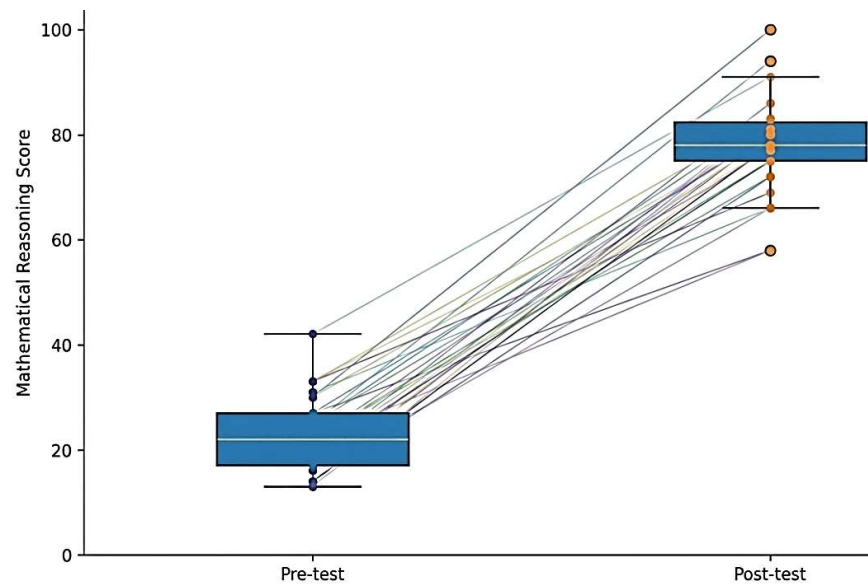


Figure 4. Scatter plots of mathematical reasoning ability

Based on the paired boxplot in Figure 4, the distribution of mathematical reasoning ability scores changed between pretest and posttest. The posttest distribution tends to be in a higher range than the pretest. In addition, the connecting lines between scores show that most students obtain higher posttest scores than pretest scores. Descriptively, these findings show a change in students' mathematical reasoning achievement

between before and after the implementation of PBL.

Data Analysis Prerequisites Test

Before multiple linear regression analysis, a prerequisite test was conducted, including tests for normality, residual normality, linearity, heteroscedasticity, and multicollinearity. The results of the prerequisite test are shown Table 3

Table 3. Prerequisite test results

Normality Test (Shapiro–Wilk)			
Variable	Test Scores	sig	Verdict
Posttest Math Anxiety	0.895	0.006	Abnormal
Posttest of Self-Efficacy	0.853	0.000	Abnormal
Posttest Reasoning Ability	0.955	0.235	Normal
Residual Normality Test			
Unstandardized Residual	0.959	0.300	Normal
Linearity Test			
Reasoning-Anxiety Skills in Mathematics	0.819	0.669	Linear
Reasoning-Self-Efficacy Skills	1.492	0.221	Linear
Heteroscedasticity Test			
Self-Efficacy	0.326	0.747	No heteroscedasticity occurs
Math Anxiety	1.068	0.295	No heteroscedasticity occurs
Multicollinearity Test			
Self-Efficacy	Tolerance = 0.237; LIFE = 4.224	-	Not Experiencing Symptoms of Multicollinearity
Math Anxiety	Tolerance = 0.237; LIFE = 4.224	-	Not Experiencing Symptoms of Multicollinearity

Based on the Shapiro–Wilk normality test results, the posttest of mathematical reasoning ability obtained a significance value of 0.235 (> 0.05), so the data are declared normally distributed. The posttest of mathematics anxiety has a significance value of 0.006, and the posttest of self-efficacy has a significance value of 0.000. Both values are less than 0.05, indicating that the data for the two variables are not normally distributed. Although some variables do not meet the normality assumption, this is not an obstacle in multiple linear regression analysis because the relevant normality assumption is the distribution of the model's residuals, not the distribution of each study variable. The residual normality test showed a significance value of 0.300 (> 0.05), indicating that the residual regression model is normally distributed. Thus, the residual normality assumption is met, and the multiple linear regression analysis can continue.

The linearity test results showed that the relationship between mathematical anxiety and mathematical reasoning ability had a deviation-from-linearity significance value of 0.669, while the relationship between self-efficacy and mathematical reasoning ability was 0.221. Both values are greater than 0.05, so the relationship between the independent variables and the dependent variable is linear. Furthermore, the Glejser heteroscedasticity test showed that self-efficacy had a significance value of 0.747 and mathematical anxiety 0.295. Because the significance values of both variables are greater than 0.05, the regression model does not exhibit heteroscedasticity.

The multicollinearity test results showed that self-efficacy and mathematical anxiety had a Tolerance value of 0.237 (> 0.10) and a Variance Inflation Factor (VIF) of 4.224 (< 10). Thus, no multicollinearity problem was found in the regression model, so the two independent variables could be analyzed simultaneously. Overall, the regression assumption test results

showed that the model met the analysis requirements, including residual normality, linearity, absence of heteroscedasticity, and absence of multicollinearity. Therefore, multiple linear regression analysis can be used to test the predictive power of mathematical anxiety and self-efficacy on mathematical reasoning ability after applying the problem-based learning (PBL) model. In addition, the improvement in mathematical reasoning skills after applying the problem-based learning (PBL) model was assessed using N-Gain.

Regarding the use of the Wilcoxon non-parametric test, and based on the research objectives and data characteristics, although the data on mathematics anxiety and self-efficacy are not individually normally distributed, both variables in this study serve as predictor variables in a multiple linear regression analysis rather than as variables compared between the pretest and posttest. Therefore, the nonnormality of individual predictor distributions is not automatically grounds for replacing regression analysis with the Wilcoxon test.

In multiple linear regression, the assumption of normality is primarily evaluated on the residual model, rather than by requiring each predictor variable to be normally distributed individually. The test results showed that the residual model was normally distributed with a significance value of 0.300 (> 0.05). In addition, the assumptions of linearity, homoscedasticity, and the absence of multicollinearity were also examined and met. Thus, multiple linear regression is still used because it aligns with the research objectives, namely analyzing the predictive power of mathematical anxiety and self-efficacy on students' mathematical reasoning skills after the application of the problem-based learning (PBL) model.

The Wilcoxon Signed-Rank Test was not used because it tests differences between two paired measurements. In contrast, this study's

regression analysis aimed to assess the predictive power of two predictor variables on one bound variable. Thus, multiple linear regression was selected because it aligns with the analysis objectives, the variable structure, and the fulfillment of relevant regression model assumptions.

Hypothesis test 1. predictive power of mathematical anxiety and partial self-efficacy on students' mathematical reasoning ability after the application of the problem-based learning model

Multiple linear regression analysis was used to determine the predictive power of

mathematical anxiety and self-efficacy on students' mathematical reasoning skills after applying the problem-based learning (PBL) model. A t-test was conducted to determine the predictive power of each independent variable for the dependent variable. The t-test results are presented in Table 4.

Based on the multiple linear regression results, mathematical anxiety has negative predictive power and is significant for students' mathematical reasoning ability after applying the problem-based learning (PBL) model. This is shown by a regression coefficient of -0.266 with a significance value of 0.004 (<0.05). A negative regression coefficient indicates that the higher the

Table 4. Results of t-test analysis

Models	Non-Standard Coefficients B	t	Sig.
(Constant)	70.509	10.972	0.000
Mathematical anxiety	-.266	-3.141	0.004
Self-efficacy	.497	6.204	0.000

student's math anxiety, the lower the mathematical reasoning ability shown.

These findings align with Demedts et al. (2022), which shows a negative relationship between math anxiety and students' math performance. These results reinforce the findings of this study that math anxiety can be a factor related to students' ability in mathematics. Math anxiety can also interfere with students' concentration in understanding and solving math problems (Möhring et al., 2024). This condition can make it difficult for students to think logically and draw conclusions when solving mathematical problems.

In contrast, the analysis shows that self-efficacy has positive and significant predictive power for students' mathematical reasoning ability after applying the problem-based learning model (PBL), with a regression coefficient of 0.497 and a significance value of 0.000 (<0.05). These results align with research by Ruijia et al.

(2022), which found That Self-Efficacy can positively predict student achievement in mathematics learning. Street et al. (2024) reinforce these findings, explaining that self-efficacy is related increased effort, perseverance, motivation, and learning behaviors that support mathematical performance. In addition, self-efficacy influences cognitive processes that can create positive or negative feedback in learning behaviors (Shengyao et al., 2024).

Hypothesis test 2. predictive power of mathematical anxiety and simultaneous self-efficacy on students' mathematical reasoning ability after the application of the problem-based learning model

"The f test was carried out to determine the predictive power of mathematical anxiety and self-efficacy simultaneously on students' mathematical reasoning skills. The results of the analysis are presented in Table 5.

Table 5. Results of the analysis of the test f together

Models	f	Sig.
1 Regression	174.058	0.000

Based on the f-test results in Table 5, a significance value of 0.000 (<0.05) was obtained, showing that mathematical anxiety and self-efficacy together have significant predictive power for students' mathematical reasoning ability after the application of problem-based learning (PBL). These findings align with Umaroh et al. (2020), which show that math anxiety and self-efficacy together affect students' mathematical reasoning skills. Theoretically, math anxiety is a negative emotional response to math that can affect an individual's academic achievement and emotional state (Navarro et al., 2026; Barroso et al., 2021). It also showed a negative relationship between math anxiety and math achievement, so students with higher anxiety tended to have lower math achievement. Meanwhile, self-efficacy reflects students' confidence in their ability to achieve goals through effort, especially when facing challenges (Hou et al., 2025).

In this study, the problem-based learning model (PBL) served as the learning treatment, while mathematics anxiety and self-efficacy were predictor variables in the regression analysis. Therefore, PBL syntax is used as a learning context to interpret these psychological findings. In the problem orientation stage, students are directed to understand the problem and identify relevant information before determining a solution strategy. This stage allows students to understand the problem more precisely before carrying out the resolution process. Furthermore, during the inquiry and group discussion stage, students can exchange ideas, compare strategies, and develop alternative solutions. These interactions can help students address problem-solving difficulties and strengthen their confidence in their abilities. In the

presenting results stage, students communicate strategies and explain the solutions they obtained. This opportunity gives students experience explaining and evaluating their thinking process. Next, the evaluation stage provides an opportunity to review the strategy's accuracy and the final results.

The series of activities shows that PBL provides a learning context that gradually involves students in understanding problems, conducting investigations, discussing, developing solutions, and communicating results. These activities can theoretically support students' experiences in dealing with math tasks and build confidence in solving problems. Thus, the results show that mathematical anxiety and self-efficacy simultaneously predict students' mathematical reasoning skills after receiving PBL treatment. In this study, PBL is still treated as a learning intervention. At the same time, empirical evidence on the predictive power of mathematical anxiety and self-efficacy for mathematical reasoning skills is based on regression analysis results.

Hypothesis 3. Improvement of students' mathematical reasoning skills after the application of problem-based learning model

The N-Gain analysis results were used to determine the magnitude of the increase in students' mathematical reasoning skills by comparing pretest and posttest scores after participating in problem-based learning (PBL). The analysis showed an average N-Gain value of 0.7117, which falls in the high category. These results show that students' mathematical reasoning skills have improved after participating in problem-based learning. To provide a more detailed picture of improvements in mathematical reasoning skills, N-Gain analysis was also carried out for each indicator of mathematical reasoning ability. The results are presented in Figure 5.

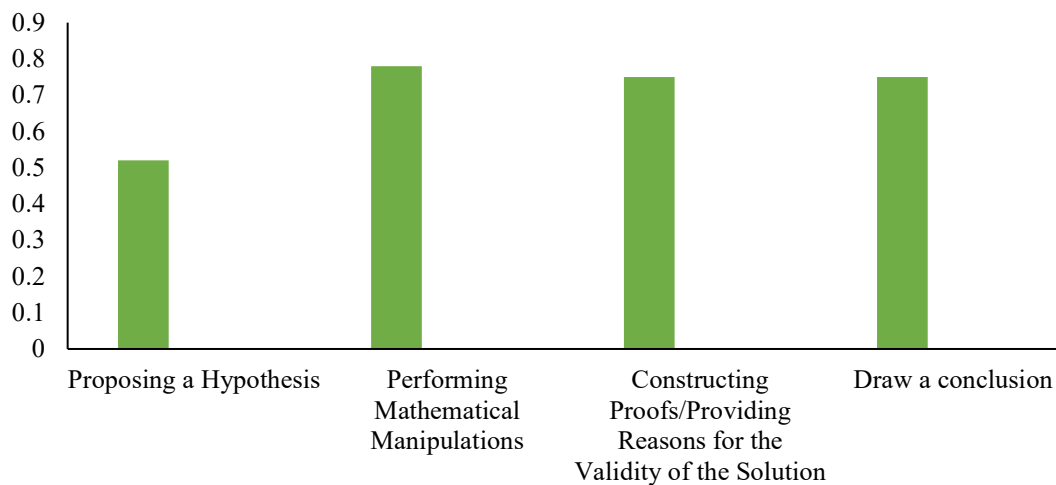


Figure 5. Improved mathematical reasoning skills based on each indicator

Based on Figure 5, the mathematical manipulation indicator had the highest N-Gain value (0.78), followed by the indicators compiling evidence or providing reasons for the correctness of the solution and drawing conclusions, each with a value of 0.75. Meanwhile, the indicator proposed the lowest N-Gain value of 0.52 in the medium category. These results show that improvement in mathematical reasoning ability does not occur equally across indicators. The large gains in the mathematical manipulation indicators can be attributed to the characteristics of the problem-based learning model, which emphasizes problem solving through the application of mathematical concepts and procedures.

Overall, the N-Gain analysis showed that students' mathematical reasoning skills improved after participating in problem-based learning (PBL), with improvement at a high level. The findings of this study align with the research of Kotto et al. (2022) and Abidah et al. (2021), which show that applying the problem-based learning (PBL) model is related to improving students' mathematical reasoning skills. However, this study differs in its focus. The research of Kotto et al. (2022) focuses more on the effectiveness of the application of PBL in improving mathematical reasoning skills, while this study

expands on the study by analyzing students' psychological factors, namely mathematical anxiety and self-efficacy, which are related to mathematical reasoning skills after participating in learning with the PBL model through multiple linear regression analysis.

This difference provides an additional perspective that mathematical reasoning ability can be assessed not only based on changes in scores before and after learning, but also through students' internal factors related to the mathematics learning process. In this study, a problem-based learning (PBL) model was used as the learning treatment to examine changes in mathematical reasoning skills based on pretest and posttest results. Meanwhile, math anxiety and self-efficacy were analyzed as psychological factors related to students' mathematical reasoning abilities after the application of problem-based learning (PBL) treatments.

Pedagogically, the findings show that developing students' mathematical reasoning skills requires consideration of both instructional and psychological aspects. Problem-based learning can provide students with a meaningful learning experience through problem-solving. This approach can be integrated with a variety of instructional methods, including digital technology and artificial intelligence (AI) as supporting tools

in problem-solving activities. This kind of integration should combine students' self-solving with teacher consultation to verify the accuracy of their reasoning, procedures, and solutions. At the same time, attention should be paid to math anxiety and self-efficacy, as both factors relate to students' ability to engage with and solve math problems. Therefore, teachers must design mathematics instruction that focuses not only on the mathematical thinking process but also on students' affective state. Flexible learning activities and edutainment elements can also be incorporated to make classroom learning more enjoyable and engaging, thus creating a more supportive and effective learning environment.

Covariance Analysis Results (ANCOVA)

The ANCOVA results showed a significance value of 0.441 (>0.05). The analysis was carried out by entering the pre-test score of mathematical reasoning ability as a covariate to control for the students' initial ability in the analysis of *post-test* scores. These results show that, after statistically accounting for initial ability, the ANCOVA analysis does not show significant results.

These findings should be interpreted in the context of a *one-group pretest-posttest* design without a control group. Therefore, a significance value of 0.441 is not used to state that problem-based learning (PBL) has no effect on mathematical reasoning ability. ANCOVA was used as an additional analysis to control for students' initial ability, while changes in mathematical reasoning ability were interpreted based on *pre-test* and *post-test results*. Thus, the interpretation of ANCOVA's results was carried out carefully and adjusted to the limitations of the research design.

■ **CONCLUSION**

This study shows that math anxiety and self-efficacy are psychological factors that have a

statistically significant relationship with students' mathematical reasoning abilities after the application of problem-based learning (PBL). In addition, students' mathematical reasoning skills improved after participating in problem-based learning (PBL), as shown by a high category of N-Gain scores. These findings show that, in mathematics learning, students' psychological factors need to be considered because mathematics anxiety and self-efficacy are related to students' ability to solve problems that require mathematical reasoning.

The practical implication of this study is that teachers need to consider students' psychological conditions when designing problem-based mathematics learning. Teachers can identify students who face obstacles in mathematics learning and provide appropriate support, such as scaffolding and constructive feedback during the problem-solving process. This support is expected to help students engage more optimally in mathematics learning activities. Further research is recommended to examine other psychological factors or use experimental research designs with comparison groups to better understand the factors that affect the development of students' mathematical reasoning skills.

■ **DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS**

During the writing of this manuscript, the author(s) used ChatGPT to assist with language refinement and proofreading. The author(s) reviewed and edited all AI-generated content and take full responsibility for the accuracy and integrity of the published article.

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