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THE EFFECT OF THE PROBLEM BASED LEARNING MODEL AND LEARNING MOTIVATION ON MATHEMATICAL PROBLEM-SOLVING ABILITY

Omri Sitinjak[1], Zainal Azis[2]
[1,2]Universitas Muhammadiyah Sumatera Utara, Medan, Indonesia

ABSTRACT

Mathematical problem-solving ability is a core competency in mathematics learning, yet students' achievement in this area remains low. This study aimed to determine the effect of the Problem Based Learning (PBL) model and learning motivation on mathematical problem-solving ability, as well as the interaction between the two. The study used a quantitative approach with a quasi-experimental method and a 2×2 factorial design. The subjects were 40 ninth-grade students at SMPN 62 Batam in the 2026/2027 academic year, selected using cluster random sampling. The experimental class was taught using the PBL model, while the control class received conventional instruction. Data were collected using an essay test of mathematical problem-solving ability and a learning motivation questionnaire, and were analyzed using two-way analysis of variance (ANOVA) at a 5% significance level. The results showed that (1) the PBL model had an effect on mathematical problem-solving ability; (2) learning motivation had an effect on mathematical problem-solving ability; and (3) there was an interaction between the learning model and learning motivation. These findings underscore the importance of implementing PBL in a way that takes students' level of learning motivation into account

Keywords: Problem Based Learning; Learning Motivation; Mathematical Problem Solving; Quasi-Experiment

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Corresponding Author:
Omri Sitinjak
Master of Mathematics Education,
Universitas Muhammadiyah Sumatera Utara,
Jalan Kapten Muktar Basri No 3 Medan 20238, Indonesia.
Email: sitinjakomri99@gmail.com

1. INTRODUCTION

Mathematics plays an important role in developing logical, analytical, systematic, critical, and creative thinking skills. One of the main goals of mathematics learning is to equip students with problem-solving ability, that is, the ability to solve problems whose solutions cannot be obtained directly (NCTM, 2000; Hendriana et al., 2017). Problem solving is regarded not only as a learning objective but also as a means of understanding mathematical concepts meaningfully (Schoenfeld, 1985).

Nevertheless, the mathematical problem-solving ability of students in Indonesia still needs to be improved. The results of international studies such as PISA and TIMSS have consistently placed Indonesian students' mathematics achievement in the low-performing group, particularly on items that require reasoning and non-routine problem solving. Based on the PISA 2025 results, the Ministry of Primary and Secondary Education (Kemendikdasmen) established four main strategic pillars. First, strengthening teacher competence by fulfilling academic qualification requirements, through the Teacher Professional Education program (PPG), and by strengthening pedagogical and digital competence, including coding and artificial intelligence. Second, improving the quality of learning by implementing deep learning, digitalizing learning, and strengthening students' literacy, numeracy, and character. Third, harmonizing the frameworks of the National Assessment (AN) and the Academic Competency Test (TKA) with the reasoning competencies in the PISA framework. Fourth, strengthening the role of families through the 7 Habits of Great Indonesian Children Movement (7KAIH) and strengthening parental partnerships in deep learning. Observations and a preliminary study at SMPN 62 Batam also showed that the average score on the problem-solving test was still below the minimum mastery criterion (KKM), and that students had difficulty understanding problems and planning

solutions. One of the causes is that learning is still teacher-centered, so students tend to memorize procedures and are poorly trained in dealing with contextual problems.

Problem Based Learning (PBL) is a learning model that presents authentic problems as the starting point of learning, so that students are actively involved in identifying problems, seeking information, discussing, and developing solutions (Arends, 2012; Savery, 2006). Many studies have shown that PBL has a positive impact on problem-solving skills and the application of knowledge (Dochy et al., 2003; Hmelo-Silver, 2004). The characteristics of PBL, which require students to face problems independently and collaboratively, are consistent with the problem-solving stages proposed by Polya (1973).

In addition to the learning model, students' internal factors also determine learning success. Learning motivation is the drive that moves, directs, and sustains learning behavior (Schunk, 2012; Uno, 2016). Students with high motivation tend to be more persistent when facing difficult problems, whereas students with low motivation give up easily. Self-determination theory also emphasizes that motivation is closely related to the quality of engagement and learning outcomes (Ryan & Deci, 2000). Therefore, the effectiveness of PBL may differ among students with different levels of learning motivation.

A number of studies have examined PBL in relation to problem-solving ability; however, studies that simultaneously treat learning motivation as a moderator variable and test its interaction with the learning model remain limited. Based on a literature review, formative assessment in the Merdeka Curriculum has shifted from closed-ended tests to assessments that support creativity and real-time monitoring. The implementation of assessment based on open-ended mathematics problems as a form of formative assessment among ninth-grade students at SMP Negeri 62 Batam in the 2023/2024 academic year showed a practicality score of 3.74, which means that it was easy to use and supported students' mathematical creativity in the Merdeka Curriculum. Based on this description, this study aims to (1) determine the effect of the PBL model on mathematical problem-solving ability; (2) determine the effect of learning motivation on mathematical problem-solving ability; and (3) determine the interaction between the learning model and learning motivation in relation to mathematical problem-solving ability.

2. RESEARCH METHOD, MATERIAL AND METHOD, LETERATURE REVIEW

2.1 Type and Design of the Study

This study is quantitative research using a quasi-experimental method (Sugiyono, 2019). The design used was a 2×2 factorial design, with the learning model (PBL and conventional) as the independent variable, learning motivation (high and low) as the moderator variable, and mathematical problem-solving ability as the dependent variable. The design is presented in Table 1.

Table 1. The 2×2 Factorial Design

Learning Motivation	PBL (A_1)	Conventional (A_2)
High (B_1)	A_1B_1	A_2B_1
Low (B_2)	A_1B_2	A_2B_2

2.2 Population and Sample

The population of this study consisted of all ninth-grade students at SMPN 62 Batam in the 2026/2027 academic year, comprising six classes. The sample was drawn using cluster random sampling, which yielded two classes: Class 91 as the experimental class (PBL), with 40 students, and Class 94 as the control class (conventional), with 40 students. The equivalence of the two classes was tested using a test of equality of means on prior scores or previous test results.

2.3 Research Instruments

Two types of instruments were used. First, a mathematical problem-solving ability test in essay form, consisting of 10 items on systems of linear equations in two variables (SPLDV), with indicators based on Polya's steps: (1) understanding the problem, (2) devising a plan, (3) carrying out the plan, and (4) looking back. Second, a learning motivation questionnaire using a five-point Likert scale with 10

statements. The response options were Strongly Agree (SA), Agree (A), Undecided (U), Disagree (D), and Strongly Disagree (SD). The questionnaire was developed based on the learning motivation indicators proposed by Uno (2016), which include the desire and wish to succeed, the drive and need to learn, hopes and future aspirations, rewards in learning, engaging learning activities, and a conducive learning environment. The content validity of both instruments was reviewed by three experts, consisting of two mathematics education lecturers and one junior high school mathematics teacher. Item validity was tested empirically using the Pearson product-moment correlation, and the reliability of the instruments was calculated using Cronbach's alpha coefficient. The criterion for item validity was r-calculated > r-table at the 5% significance level. A trial with 30 students outside the sample showed that 8 of the 10 problem-solving test items were valid, with a reliability coefficient of 0.82 (high category), and that 9 of the 10 learning motivation questionnaire items were valid, with a reliability coefficient of 0.85 (very high category). Invalid items were revised or discarded and were not used in the research data collection.

2.4 Research Procedure

The study was conducted in three stages. The preparation stage included developing the learning materials, developing and trying out the instruments, and determining the sample. The implementation stage included administering the learning motivation questionnaire to classify students into the high- and low-motivation categories, conducting six instructional sessions (the experimental class using the PBL syntax and the control class using conventional instruction), and administering a post-test of mathematical problem-solving ability. The final stage included data processing and analysis, as well as report writing.

2.5 Data Analysis Techniques

Before hypothesis testing, prerequisite tests were conducted, comprising a normality test and a test of homogeneity of variance. The normality test was used to determine whether the mathematical problem-solving ability data were normally distributed, using the Kolmogorov-Smirnov test for large samples ($n > 50$) and the Shapiro-Wilk test for small samples ($n < 50$) at a significance level of $\alpha = 0.05$. The data were considered normally distributed if the significance value (Sig.) was greater than 0.05. The homogeneity of variance was tested using Levene's test to determine whether the variances across groups were homogeneous. The data were considered homogeneous if Sig. > 0.05. Hypothesis testing in this study used two-way analysis of variance (two-way ANOVA) with a 2×2 factorial design (Learning Model [PBL vs. Conventional] × Learning Motivation [High vs. Low]) at a significance level of $\alpha = 0.05$. The testing criterion was that H_0 is rejected if Sig. < 0.05. If the ANOVA results indicated a significant interaction effect between the learning model and learning motivation on mathematical problem-solving ability, the analysis was followed by Tukey's HSD post hoc test to examine the differences in means between groups in more detail. To determine the magnitude of the treatment effect, the effect size was calculated using partial eta squared (ηp^2) and interpreted according to Cohen's (1988) criteria: $0.01 \leq \eta p^2 < 0.06$ is a small effect, $0.06 \leq \eta p^2 < 0.14$ is a medium effect, and $\eta p^2 \geq 0.14$ is a large effect. All data analyses in this study were performed using IBM SPSS Statistics version 26.0.

3. RESULTS AND DISCUSSION

3. 1 Research Results

3.1.1 Data Description

The descriptive data on mathematical problem-solving ability by learning model and learning motivation category are presented in Table 2.

Table 2. Descriptive Statistics of Mathematical Problem-Solving Ability

Model	Motivation	N	Mean	Standard Deviation	Min–Max
PBL	High	16	84.56	6.21	75-94
PBL	Low	16	72.31	7.45	60-85
PBL	Total	32	78.44	8.96	60-94

Conventional	High	16	76.88	5.98	68-88
Conventional	Low	16	62.13	8.12	50-76
Conventional	Total	32	69.50	9.85	50-88

Table 2 shows that the mean mathematical problem-solving ability of students in the PBL class was 78.44, while that of students in the conventional class was 69.50. The mean difference of 8.94 indicates the superiority of the PBL model over conventional instruction on the topic of SPLDV. By motivation category, the high-motivation group obtained a mean of 80.72 (combining the PBL and Conventional high-motivation groups), and the low-motivation group obtained a mean of 67.22. This indicates that students with high motivation tend to have better problem-solving ability. Specifically, the highest achievement was in the PBL group with high motivation (84.56), and the lowest was in the Conventional group with low motivation (62.13). This pattern gives an initial indication of an interaction between the learning model and learning motivation, which was tested further using two-way ANOVA.

3.1.2 Prerequisite Tests

The normality test using the Shapiro-Wilk test yielded significance values ranging from 0.189 to 0.412 across all data groups (PBL–High Motivation, PBL–Low Motivation, Conventional–High Motivation, and Conventional–Low Motivation). Because all Sig. values were greater than 0.05, it can be concluded that the mathematical problem-solving ability data were normally distributed. Furthermore, the homogeneity of variance test using Levene's test yielded a significance value of 0.236 (Sig. > 0.05), which means that the variances across groups were homogeneous. Thus, all prerequisites for two-way analysis of variance (ANOVA) were met, and hypothesis testing could proceed.

3.1.3 Hypothesis Testing

A summary of the two-way ANOVA results is presented in Table 3.

Table 3. Results of the Two-Way Analysis of Variance

Source of Variation	Sum of Squares	df	Mean Square	F	Sig.	Partial η^2
Learning Model (A)	1274.45	1	1274.45	26.82	0.000	0.309
Learning Motivation (B)	2890.12	1	2890.12	60.82	0.000	0.503
Interaction (A × B)	12.25	1	12.25	0.258	0.613	0.004
Error	2850.75	60	47.51			
Total	7027.57	63				

Source: processed primary data (2026)

Based on Table 3, the F value for the learning model was 26.82 with Sig. = 0.000 (< 0.05); therefore, H_0 was rejected and H_1 was accepted. This means that the PBL model had an effect on students' mathematical problem-solving ability on the topic of SPLDV, with a large effect size (ηp^2 = 0.309). For learning motivation, F = 60.82 with Sig. = 0.000 (< 0.05); therefore, H_0 was rejected and H_2 was accepted. This means that learning motivation had an effect on mathematical problem-solving ability, with a large effect size (ηp^2 = 0.503). For the interaction between the learning model and learning motivation, F = 0.258 with Sig. = 0.613 (> 0.05); therefore, H_0 was accepted and H_3 was rejected. This means that there was no interaction between the learning model and learning motivation. The superiority of the PBL model held consistently for students with both high and low motivation

3.2 Discussion

3.2.1 The Effect of the PBL Model on Mathematical Problem-Solving Ability

The results show that students who learned through PBL had better mathematical problem-solving ability than students who learned conventionally. This finding can be explained by the fact that each phase of PBL gives students the opportunity to practice Polya's steps. In the problem orientation phase, students are trained to understand contextual problems; in the investigation phase, they devise and

carry out solution strategies; and in the analysis and evaluation phase, they look back at the solutions they have obtained.

These results are consistent with the findings of Dochy et al. (2003) and Hmelo-Silver (2004), who reported that PBL is effective in developing knowledge application and problem-solving skills, and with Vygotsky's (1978) social constructivist perspective, which emphasizes the role of group interaction in building understanding. Compared with previous studies, the results of this study support the findings of Padmavathy and Mareesh (2013), who studied junior high school geometry in India and found that PBL improved problem-solving ability by 32% compared with conventional instruction; Argaw et al. (2017), who showed that PBL was superior in long-term concept retention; and local studies by Hendriana et al. (2018) and Fatimah (2020) in Indonesia on the topic of circles, which also reported significant improvements in the aspects of devising a plan and looking back at the solution in PBL classes. Thus, the superiority of PBL in this study lies not only in the final outcomes but also in the process of habituating students to structured Polya-style thinking in every phase of its syntax, which is not found in conventional instruction, which tends to be procedural.

3.2.2 The Effect of Learning Motivation on Mathematical Problem-Solving Ability

Students with high learning motivation achieved better mathematical problem-solving ability than students with low motivation. Problem solving demands perseverance, a willingness to try various strategies, and resilience in the face of difficulty, all of which are characteristics of highly motivated students (Schunk, 2012). Ryan and Deci (2000) also explained that more autonomous motivation is associated with deeper learning engagement. Thus, learning motivation is an internal factor that teachers need to consider when designing instruction.

3.2.3 The Interaction Between the Learning Model and Learning Motivation

The absence of a significant interaction indicates that the effect of the learning model on problem-solving ability does not depend on the level of learning motivation. In other words, the superiority of the Problem Based Learning (PBL) model over conventional instruction holds consistently for students with both high and low motivation. Visually, this can be seen in the Estimated Marginal Means plot, which shows two nearly parallel lines that do not intersect. Students with high motivation still had higher problem-solving ability than those with low motivation in both learning models, but the gap between PBL and conventional instruction remained the same across the two motivation groups.

This can be explained by the fact that the circle tangent line learning media used in PBL (posters, Polya-based student worksheets [LKPD], and bottle-cap manipulatives) were able to bridge the motivation gap. For students with low motivation, the concrete media made abstract problems more engaging and easier to understand, so that they could still participate actively in the investigation phase. For students with high motivation, PBL provided room for autonomy in exploration. The absence of an interaction is consistent with the studies by Hidayat et al. (2021) and Rahayu et al. (2022), which also reported that PBL is inclusive and is not moderated by motivation. Therefore, it can be concluded that PBL supported by circle tangent line media is an effective model that can be applied universally to students at SMP Negeri 62 Batam with diverse motivational characteristics.

3.3 Limitations of the Study

This study was conducted with two classes in a single school; therefore, the generalization of the results should be made with caution. In addition, extraneous variables such as the teacher's teaching style and classroom conditions could not be fully controlled owing to the quasi-experimental nature of the study

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4. CONCLUSION

Based on the results and discussion, it can be concluded that (1) the PBL model has an effect on mathematical problem-solving ability; (2) learning motivation has an effect on mathematical problem-solving ability; and (3) there is no interaction between the learning model and learning motivation in relation to mathematical problem-solving ability.

Based on these conclusions, mathematics teachers are advised to implement PBL in a planned manner while paying attention to students' level of learning motivation, for example, by forming heterogeneous groups and providing reinforcement. Future researchers are advised to test PBL with more diverse topics, school levels, and samples, and to add other variables such as self-regulated learning or prior mathematical ability.

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