



Effect of problem-based learning model on critical thinking and Math learning motivation

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ABSTRACT

Critical thinking ability and learning motivation are two essential aspects of mathematics learning that are closely interrelated. Low cognitive and affective engagement among students is often caused by instructional approaches that fail to support higher-order thinking activities. This study aims to analyze the influence of the Problem-Based Learning model on students' critical thinking ability and mathematics learning motivation. The research employed a quantitative approach using a quasi-experimental design involving two classes of seventh-grade students at MTs Jam'iyah Mahmudiyah Tanjung Pura. The instruments included essay tests to assess critical thinking skills and Likert-scale questionnaires to measure students' motivation. The results of the normality and homogeneity tests confirmed that the data were normally distributed and had homogeneous variance, allowing the use of Two-Way ANOVA and the Mann-Whitney test for further analysis. The findings indicated that Problem-Based Learning was significantly more effective than direct instruction in enhancing both critical thinking and motivation. Moreover, an interaction effect between students' prior mathematical ability and the learning model was observed. This research highlights the importance of implementing problem-based learning strategies that respond to individual differences in students' needs and abilities.

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ABSTRAK

Kemampuan berpikir kritis dan motivasi belajar merupakan dua aspek penting dalam pembelajaran matematika yang saling berhubungan. Rendahnya keterlibatan kognitif dan afektif siswa dalam proses belajar sering kali disebabkan oleh pendekatan pembelajaran yang tidak memfasilitasi aktivitas berpikir tingkat tinggi. Penelitian ini bertujuan untuk menganalisis pengaruh model Problem-Based Learning terhadap kemampuan berpikir kritis dan motivasi belajar matematika siswa. Penelitian ini menggunakan pendekatan kuantitatif dengan desain eksperimen semu dan melibatkan dua kelas siswa tingkat VII di MTs Jam'iyah Mahmudiyah Tanjung Pura. Instrumen yang digunakan mencakup tes uraian untuk mengukur kemampuan berpikir kritis serta angket skala Likert untuk menilai motivasi belajar matematika siswa. Hasil analisis menunjukkan bahwa data berdistribusi normal dan memiliki varians yang homogen, sehingga pengujian menggunakan ANOVA dua jalur dan uji Mann-Whitney dapat dilaksanakan. Temuan menunjukkan bahwa pembelajaran menggunakan model Problem-Based Learning secara signifikan lebih efektif dibandingkan pembelajaran langsung dalam meningkatkan kedua variabel tersebut. Interaksi antara kemampuan awal matematika dan model pembelajaran juga berpengaruh terhadap hasil belajar. Penelitian ini memperkuat urgensi penerapan pendekatan pembelajaran berbasis masalah yang adaptif terhadap kebutuhan dan kemampuan siswa.

Kata Kunci: berpikir kritis; Matematika; motivasi belajar; problem-based learning

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INTRODUCTION

Critical thinking skills in basic mathematics learning are a key element in developing higher-order thinking skills relevant to the demands of the 21st century. Mathematics serves not only as a vehicle for practicing logic and systematic reasoning, but also as a means of solving life's problems through rational thought processes (Nurrawi *et al.*, 2023). The application of a learning model that facilitates active student involvement is essential to optimize the thinking process (Setiawan *et al.*, 2024). The *Problem-Based Learning* (PBL) model is considered effective in creating challenging learning experiences, encouraging students' independent exploration of complex real-world problems, and increasing students' cognitive engagement and internal motivation (Santos-Meneses *et al.*, 2023).

Improving critical thinking skills will not be optimal without strong motivational support from within the students. Low motivation to learn is often a major obstacle to understanding concepts, especially in mathematics, which requires perseverance, interest, and intellectual courage (Nurrawi *et al.*, 2023; Puspitasari & Sari, 2024). A correlation between low learning motivation and weak critical thinking skills has been found in various studies, including one showing that students with low levels of motivation tend to fail to develop in-depth logical reasoning. The relationship between these two aspects reinforces the urgency of designing learning approaches that can simultaneously build students' cognitive and affective capacities.

Epistemological barriers are among the most common conceptual problems students encounter when learning mathematics. These difficulties arise because students lack motivation to engage in higher-order thinking that requires a deep understanding of mathematical concepts and relationships (Baharullah *et al.*, 2022). Students tend to avoid reflective thinking and instead adopt mechanistic strategies that do not produce complete conceptual understanding (Agus *et al.*, 2025). This weakness indicates that understanding is procedural rather than structural, owing to students' lack of motivation to learn from within (Noviyanti *et al.*, 2021).

Understanding the dimensions of critical thinking and aspects of learning motivation serves as a theoretical foundation for developing effective learning designs. Critical thinking consists of four main dimensions: interpretation, analysis, evaluation, and inference (Ayu *et al.*, 2023). These four dimensions describe the logical and systematic thinking processes required to construct arguments, evaluate information, and make rational decisions. Learning motivation, on the other hand, encompasses indicators such as the desire to succeed, the need to learn, future expectations, appreciation for the process, and a supportive learning environment (Astiantari *et al.*, 2022). The synergy between critical thinking and learning motivation is a key prerequisite for creating an active, reflective, and meaningful learning process.

The relevance of critical thinking and learning motivation becomes increasingly clear when students are confronted with mathematical material that requires problem-solving based on abstract reasoning, such as algebra. Understanding algebraic concepts requires students to build symbolic relationships, formulate problem-solving strategies, and logically test the validity of solutions. These three activities not only involve high-level cognition but also require internal motivation to sustain students' persistence and focus in solving the problems they face (Mawaddah *et al.*, 2024). When critical thinking and motivation are aligned, students' problem-solving abilities develop significantly.

The contextual problems encountered in seventh-grade students at MTs Jam'iyah Mahmudiyah Tanjung Pura reflect the real-world complexity of mathematics learning. Initial observations indicate that most students have difficulty solving context-based algebra problems. Students are unable to interpret information, construct mathematical models, and draw conclusions based on logical steps. This weakness indicates that critical thinking indicators, such as interpretation, analysis, evaluation, and inference, have not been fully developed. Low learning motivation further exacerbates this situation, as students exhibit a

passive attitude, are reluctant to discuss, and lack interest in completing learning assignments (Aninditaningrum *et al.*, 2024).

Classroom learning remains conventional and teacher-centered, dominated by direct explanations, with little room for discussion or independent exploration. Students are passive recipients of information and are not trained to develop understanding through experience. This lack of active participation in learning prevents students from developing sensitivity to complex mathematical problems and from reflecting on and constructing knowledge in meaningful ways. This situation indicates the need for a transformation in pedagogical approaches to make learning more interactive and participatory.

The PBL model is a relevant strategic alternative for addressing these challenges because it emphasizes thinking processes, group work, and contextual problem-solving. Implementing this model enables students to build understanding through independent investigation, collaborative discussion, and reflection on the solutions they develop (Nurlaeli, 2022). Active involvement in the problem-solving process has been shown not only to improve critical thinking skills but also to strengthen students' intrinsic motivation for learning mathematics (Marlina *et al.*, 2023). Therefore, empirical testing of the effectiveness of the Problem-Based Learning model is needed to ensure its contribution to strengthening critical thinking skills and increasing students' learning motivation.

Previous research showed a significant increase in students' cognitive engagement in mathematical contexts following the implementation of the PBL model (Fatayan *et al.*, 2022). The effectiveness of this model in fostering higher-order thinking and learning motivation has also been demonstrated through a meta-analysis (Xu *et al.*, 2023). The consistent implementation of PBL increases students' independence and perseverance in solving open-ended questions based on contextual problems (Almarashdi & Jarrah, 2022). Students' initial abilities also influence the success of implementing this model, particularly in reasoning about abstract mathematical concepts (Kania *et al.*, 2023). These findings strengthen the case for further in-depth research on the PBL model in mathematics learning at the MTs level.

This study was designed to examine the effect of the PBL model on students' critical thinking skills and learning motivation in mathematics learning. The main objective of this study was to determine whether learning outcomes differed between students taught using the PBL model and those receiving direct instruction with respect to critical thinking skills and learning motivation. This study also aims to determine whether an interaction exists between students' initial mathematical abilities and the learning model used, in relation to the development of critical thinking and motivation to learn mathematics. Through this study, it is hoped that a more comprehensive understanding of the effectiveness of the PBL model as an alternative learning approach will be gained, thereby increasing students' cognitive and affective engagement. The findings of this study can also serve as a basis for designing learning strategies that are more contextual and oriented toward the development of higher-order thinking skills, thereby improving the quality of mathematics learning at the elementary and secondary education levels.

LITERATURE REVIEW

Critical Thinking Skills

Critical thinking is essential in 21st-century learning because it enables students to evaluate information, develop logical arguments, and make informed decisions based on evidence (Prajon *et al.*, 2022). This skill is highly relevant in mathematics learning, which demands precision, systematic reasoning, and high-level conceptual understanding. The four main dimensions of critical thinking include interpretation, analysis, evaluation, and inference (Rismayanti *et al.*, 2022). Interpretation involves understanding the meaning of information, analysis refers to identifying logical relationships between components, evaluation

relates to assessing the strength of an argument, and inference refers to the ability to draw logical conclusions from available data.

The development of critical thinking can be achieved only through a learning process that emphasizes exploration, discussion, and reflection centered on students' thinking. This development is influenced by a learning design that provides opportunities for students to present reasons, construct ideas, and test assumptions used in the problem-solving process (Khoirunnisa & Malasari, 2021). Reflective thinking strategies are important in mathematics learning because they provide a logical basis for students to select appropriate solution procedures and avoid conceptual errors (Nababan, 2021).

Success in developing critical thinking skills is also influenced by students' character and attitudes toward learning, such as self-confidence, perseverance, and openness to new ideas. A learning process that values argumentation and open dialogue allows students to develop independent and balanced thinking skills (Wilujeng & Sudihartinih, 2021). Therefore, learning oriented toward strengthening critical thinking not only supports academic achievement but also fosters essential life skills for reflecting on the complexities of the real world.

Learning Motivation

Learning motivation is an affective component that serves as the primary driving force in the learning process and determines the extent to which students are actively engaged in learning activities. (Budiningsihet *et al.*, 2024) A high level of motivation encourages students to be diligent, take initiative, and persevere in completing learning tasks. In contrast, low motivation tends to lead to a passive attitude, giving up easily, and minimal participation. (Wijayanti & Widodo, 2021) Learning motivation is influenced by various internal and external factors, including the desire to succeed, the need for achievement, future aspirations, a conducive learning environment, and positive learning experiences. (Winahyuet *et al.*, 2024).

The structure of learning motivation encompasses several interrelated indicators that shape a student's emotional engagement in learning. These indicators include the desire to achieve success, an intrinsic drive to learn, interest in learning activities, and the student's ability to maintain focus despite difficulties (Irnawati *et al.*, 2024). When motivation is intrinsic, students will demonstrate consistent enthusiasm for learning and will not depend entirely on external rewards. (Budi *et al.*, 2024). This condition makes the learning process more meaningful because it is driven by personal awareness and a desire for personal development.

The presence of learning motivation is crucial to mathematics learning, which entails high intellectual challenges. Without motivation, students will tend to avoid activities that require cognitive effort, such as problem-solving or understanding abstract concepts (Siregar *et al.*, 2024). When motivation is optimally present, students are more open to trying new strategies, working hard on difficult problems, and are more ready to accept feedback as part of the learning process (Ridgley *et al.*, 2022). Strong motivation not only increases participation but also strengthens self-confidence and perseverance in the face of learning challenges.

The role of educators in building and maintaining learning motivation is crucial to the success of the learning process. Designing learning activities that are engaging, interactive, and relevant to students' lives will significantly foster interest and enthusiasm for learning (Khaira *et al.*, 2023; Maryanti, 2024). A positive, participatory learning environment that values students' efforts has been shown to foster sustainable intrinsic motivation (Hasanah *et al.*, 2024; Rosyiddin *et al.*, 2023). Learning strategies that attend to affective aspects not only improve the quality of the learning process but also encourage students' emotional engagement, which directly impacts academic achievement, particularly in mathematics, which demands high cognitive effort and perseverance.

PBL Learning Model

The PBL model is a learning approach that emphasizes students' active involvement in contextual problem solving to build knowledge and skills (Arisandi, 2024). This learning approach positions students as the primary subjects in the learning process. Students are encouraged to explore, develop arguments, and seek solutions through collaborative discussions and independent reflection. Collaborative discussions and independent reflection naturally foster higher-order thinking skills, including critical thinking, problem-solving, and decision-making (Cojorn, 2024). This situation illustrates that momentary emotions do not solely influence motivation; rather, they are shaped by students' self-perceptions, educators' teaching strategies, and consistent learning contexts. The presence of a learning model that can stimulate student interest and active engagement is essential to sustaining learning motivation.

PBL emphasizes presenting real-world problems as an initial stimulus to encourage students to build conceptual understanding gradually. In PBL, educators act as facilitators, guiding students through the scientific inquiry process without directly providing solutions (Handoyo *et al.*, 2024). The stages in this model generally include orientation to the problem, organization of learning activities, individual or group investigation, development and presentation of work results, as well as reflection and evaluation of the process that has been undertaken (Masruro *et al.*, 2024). Student involvement at each stage is designed to create meaningful learning experiences and develop intellectual independence.

Research has shown that PBL in mathematics learning improves critical thinking skills and motivates students to be more actively involved in the learning process (Ratnawati *et al.*, 2024). Learning activities that begin with real problems encourage students to connect mathematical concepts to concrete situations they encounter in their daily lives (Ardanari *et al.*, 2024). The connection between the material and the context of life makes learning more relevant and stimulates curiosity, which ultimately strengthens students' intrinsic motivation to understand and master the material.

The PBL model also provides ample opportunities for social interaction among students through group discussions, idea exchange, and collaborative problem-solving. This learning environment fosters not only academic skills but also essential social and communication skills for facing the complex challenges of the future (Latifah, 2024). Therefore, PBL is considered a learning approach that can meet the needs of 21st-century education, which emphasizes mastery of critical thinking, problem-solving, and teamwork.

The theoretical application of the PBL model is strongly rooted in the constructivist approach, which emphasizes that individuals actively construct knowledge through interaction with the environment and learning experiences (Rizki *et al.*, 2024). The constructivist view holds that the learning process is not a passive activity of receiving information, but rather a process of constructing meaning based on understanding developed by the learner themselves. Therefore, learners must be allowed to explore, ask questions, construct arguments, and reflect on their experiences in relevant contexts (Faisal *et al.*, 2024).

PBL reflects the essence of constructivism by providing authentic learning situations and encouraging cognitive conflict as a catalyst for thinking. Through exposure to real-world problems, students are encouraged to revise their understanding, align new knowledge with existing schemata, and construct more meaningful knowledge. The social interactions that occur in group discussions also play a crucial role in broadening perspectives and testing the validity of arguments, which are central to meaningful learning in a constructivist approach (Taufik, 2024). Educators in this framework act as facilitators who help students direct inquiry rather than as the primary source of knowledge. Therefore, the PBL model aligns philosophically and practically with the principles of constructivism as a foundation for developing participatory, reflective, and contextual learning.

Learning model: *Direct Interaction*

The direct learning model is an instructional approach that systematically delivers information from educators to students through structured stages. The interaction pattern in this model is dominated by the educator's activities as the primary source of knowledge, explicitly explaining the material, providing examples, and guiding exercises to ensure students' understanding of the concepts being taught (Buyung *et al.*, 2024). The learning stages typically include articulating objectives, providing an initial stimulus, presenting information, guided practice, independent practice, and assessing learning outcomes (Carlina & Fadliansyah, 2024).

This model is widely used in learning that emphasizes time efficiency, clarity of material, and procedural accuracy. Direct instruction is ideal for building initial understanding of new concepts or systematically teaching basic skills (Mastura *et al.*, 2024). The process of delivering material coherently, combined with reinforcement through intensive practice, facilitates students' ability to remember and apply information appropriately (Nurjanah *et al.*, 2024). The success of implementing this model depends on the clarity of the educator's communication, the accuracy of the selected examples, and the consistency with which feedback is provided to students.

The advantage of the direct learning model lies in its effectiveness in conveying factual and procedural information quickly and in a structured manner. This approach enables educators to fully control the learning process, thereby facilitating the achievement of learning objectives in a relatively short time. (Febrianty *et al.*, 2024). However, direct learning has limitations in developing higher-order thinking skills, as students tend to function as recipients of information and are afforded insufficient space to construct knowledge independently (Bangki *et al.*, 2024; Hartati *et al.*, 2024). Dependence on educators' directions also risks reducing students' motivation and independence in learning, especially in complex and contextual learning (Sirajuddin, 2024).

Nevertheless, the direct learning model remains relevant for certain instructional purposes, particularly when students require structural clarity, procedural clarity, and a focus on mastering basic concepts. Its application needs to be balanced with other, more interactive learning approaches so that students not only master declarative knowledge but also apply it critically in broader contexts.

METHODS

This research uses a quantitative approach with a quasi-experimental method (*quasi-experimental design*), which aims to test the influence of the PBL model on students' critical thinking skills and motivation to learn mathematics. The research design employed a Nonequivalent Control Group Design, comprising two groups of students: the experimental group, which received PBL treatment, and the control group, which received direct instruction. Both groups were administered pre- and post-tests to measure differences in learning outcomes before and after treatment. The study population comprised all seventh-grade students at MTs Jam'iyah Mahmudiyah Tanjung Pura in the 2024/2025 academic year. The sampling technique was purposive, accounting for the equality of academic characteristics across classes. The research sample comprised two classes, each with 30 students, and participants were allocated proportionally to experimental and control groups.

The research instruments used included a critical thinking test and a learning motivation questionnaire. The critical thinking test was designed based on critical thinking indicators relevant to mathematics content, while the learning motivation questionnaire was developed with reference to intrinsic and extrinsic motivation. The validity of the instruments was assessed through expert assessment, and their reliability was assessed using Cronbach's *Alpha*. The data analysis employed parametric statistics, namely the t-test and two-way ANOVA, to examine differences and interactions among the variables studied. The

research implementation procedure included the preparation stage, treatment implementation, data collection, and analysis of results. The preparation stage involved developing learning tools and evaluation instruments. The implementation stage included administering a pretest, implementing learning according to the model within each group, and administering a posttest. Data analysis is conducted after all data have been collected to test hypotheses and draw conclusions based on the research results.

RESULTS AND DISCUSSION

Validation Results of Learning Devices and Instruments

Validation of the learning tools and instruments was conducted to ensure the suitability of all components used to measure study outcomes. The validation process involved experts in assessing the Lesson Implementation Plan (RPP), the student learning motivation questionnaire, the Group Worksheet, and the student learning outcome test. The assessment of the four instruments indicated that the RPP and Group Worksheet were classified as "Fair". In contrast, the student learning motivation questionnaire and the student learning outcome test were rated "Good" for validation, as shown in **Table 1**.

Table 1. Learning Device Validation Results

No	Objects being assessed	Validation level
1	Lesson plan	Pretty good
2	Student mathematics learning motivation questionnaire	Good
3	Group worksheet	Pretty good
4	Student learning outcome test	Good

Source: Research 2025

These findings indicate that the developed learning tools and instruments are suitable for empirically measuring students' critical thinking skills and learning motivation. Further validity testing of the critical thinking test was conducted by examining content and empirical validity using Pearson product-moment correlation analysis. This technique is used to correlate individual item scores with the total score to ensure each item consistently measures the intended aspect. The instrument's validity provides the basis for proceeding to the reliability testing stage. This stage aims to assess the consistency of measurement results when the instrument is used repeatedly on the same group of subjects. An instrument is considered reliable if it yields consistent results and does not exhibit significant variation across repeated measurements.

The next step is to analyze the discriminative power and difficulty of the test items. This analysis aims to identify the quality of each test item, including the extent to which it can differentiate between students with high and low levels of mastery. The difficulty level is used to assess the extent to which students with average abilities can answer the test items. The complete results of the critical thinking instrument test for students are presented in **Table 2**.

Table 2. Critical Thinking Ability Test Trial Results

Question number	Differential power		Difficulty level		Validity	
1	0.35	Good	0.52	Currently	0.99	Valid
2	0.4	Good	0.61	Currently	0.96	Valid
3	0.28	Enough	0.57	Currently	0.98	Valid
4	0.29	Good	0.61	Currently	0.97	Valid
5	0.35	Good	0.52	Currently	0.99	Valid
Reliability coefficient				0.77		

Source: Research 2025

Critical Thinking Skills Analysis

A normality test was conducted to assess whether the data on the improvement in students' critical thinking skills in mathematics in the experimental and control groups were normally distributed. The analysis was conducted using the Kolmogorov-Smirnov and Shapiro-Wilk techniques operated through the SPSS version 22 program. Decision making was based on the significance value, where the data was declared normally distributed if the significance value was greater than 0.05, as shown in **Table 3**.

Table 3. Normality Test of Critical Thinking Ability

	Class	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
NGain_Percent	Experiment	.09	30	.20*	.95	30	.18
	Control	.20	30	.00	.93	30	.06

Source: Research 2025

Based on **Table 3**, the Shapiro-Wilk significance value for the experimental group was 0.18, and for the control group was 0.06. All of these values are greater than the established significance limit, thus concluding that the data distribution in both groups is within the normal range. This finding is an important prerequisite for proceeding to the homogeneity of variance test.

A normality test was conducted to assess whether the data on the improvement in students' critical thinking skills in mathematics in the experimental and control groups were normally distributed. The analysis was conducted using the Kolmogorov-Smirnov and Shapiro-Wilk techniques using SPSS version 22. Decisions were based on the significance level, with the data considered normally distributed if the p-value exceeded 0.05.

Table 4. Homogeneity Test of Variance of Experimental and Control Groups

LeveneStatistic	df1	df2	Say.
.764	1	58	.386

Source: Research 2025

Table 4 shows that the Levene's Test statistic is 0.386, which exceeds the 0.05 threshold. This value indicates that the variance in the data between the experimental and control groups is homogeneous. Therefore, the data meet two important requirements: normality and homogeneity of variance, thereby enabling valid further analysis using two-way ANOVA.

Two-way ANOVA analysis

A two-way ANOVA was used to test the effects of the learning model and initial mathematics abilities on students' critical thinking skills. This test also aims to determine the interaction between the two independent variables on the dependent variable. The test results show that the initial mathematics ability variable has a significant effect on improving critical thinking skills, with a significance value of 0.00 and an F value of 123.06. The treatment group also showed a significant difference ($p = 0.00$; $F = 47.25$). This indicates that the learning models used, namely PBL and direct learning, have a significant effect on improving students' critical thinking skills.

Table 5. Two-Way ANOVA Test Results of Critical Thinking Ability Gain

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	80241.8 ^a	5	16048.37	82.33	.00
Intercept	57469.93	1	57469.93	294.82	.00
Student Abilities	47977.62	2	23988.81	123.06	.00
Group	9210.25	1	9210.25	47.25	.00
Student Ability * Group	1468.49	2	734.24	3.76	.02
Error	10526.04	54	194.92		
Total	172528.74	60			
Corrected Total	90767.92	59			

a. R Squared = .884 (Adjusted R Squared = .873)

Source: Research 2025

The interaction between initial mathematics ability and the learning model was also statistically significant, with a p-value of 0.02 and an F-value of 3.76. These findings indicate that students' initial mathematics ability levels influence the effect of the learning model on critical thinking skills. The combination of these two factors influences the extent to which students can experience optimal improvement in critical thinking skills.

These findings provide statistical evidence that the use of the PBL model has a direct positive effect and that its effectiveness varies with students' initial mathematical abilities. Therefore, this learning model warrants consideration as a differentiated approach to improving critical thinking skills among junior high school students.

Analysis of Mathematics Learning Motivation

Students' mathematics learning motivation was analyzed using questionnaire data from two groups: the experimental class using the PBL model and the control class following regular instruction. The questionnaire consisted of positive and negative statements with four-choice scales and was then classified into very high, high, low, and very low categories based on total score. The treatment employed algebra, and the study was conducted with class VII-A students at MTs Jam'iyah Mahmudiyah Tanjung Pura to assess differences in learning motivation between the two groups. The results of the distribution of students' learning motivation are presented in **Table 6**.

Table 6. Results of Students' Mathematics Learning Motivation

Total score	Learning interest categories	Frequency	
		Experiment	Control
25-49	Very low	0	1
50-69	Low	2	3
70-79	High	7	7
80-100	Very high	21	19

Source: Research 2025

Table 6 shows that in the experimental class, there were 21 students with very high motivation, 7 with high motivation, and 2 with low motivation. No students were found in the very low category. Meanwhile, in the control class, 19 students had very high motivation, 7 had high motivation, 3 had low motivation, and 1 had very low motivation.

Discussion

The improvement in students' critical thinking skills in mathematics in this study showed the strongest pattern in the medium initial ability category, followed by the high category. In contrast, the lowest improvement was recorded in the low category. This pattern is consistent with previous findings highlighting the effectiveness of the PBL model among students with medium ability (Faisal *et al.*, 2024). The inequality in response levels across categories is also reflected in studies showing that the critical thinking skills of students with low initial abilities tend to increase only modestly, even when using the PBL approach (Hasanah *et al.*, 2024). The effectiveness of PBL is more consistent when delivered to students with intermediate learning readiness, as they are better able to understand the problem context and are actively involved in the problem-solving process (Robbani & Sumartini, 2023).

Similar implications are evident in research showing that students in the medium-ability category demonstrated the greatest improvement in the interpretation and analysis aspects of critical thinking after applying problem-based learning (Ayu *et al.*, 2023). Positive responses to PBL tend to be high in the middle group due to the balance between challenges and abilities, while students in the low category require additional mentoring strategies (Ardanari *et al.*, 2024). Other research supports these results, asserting that the effectiveness of PBL depends on the match between the complexity of the problem and students' initial abilities, particularly in the context of elementary mathematics learning (Marlina *et al.*, 2023).

Interest in an activity develops alongside enjoyment and deep emotional involvement. The results of this study indicate that implementing the PBL model can more effectively stimulate students' motivation to

learn mathematics than direct instruction. In the experimental class, the majority of students were in the very high and high categories. In contrast, in the control class, the motivation category was very low, although most were in the high category. This distribution reflects a positive pattern of increasing learning motivation after the implementation of PBL (Ratnawati *et al.*, 2024).

Statistical tests confirmed a significant difference in mean between the two groups. The average mathematics learning motivation in the experimental class was 83, higher than that in the control class (80.3). The Mann-Whitney test produced an Asymp. Sig. value of 0.016, which is below the 0.05 threshold, indicating a significant difference between the two groups. This finding indicates that more effective implementation of PBL improves students' affective outcomes (Hartati *et al.*, 2024).

This finding is consistent with previous research, which shows that problem-based learning has a positive impact on students' learning motivation, especially in exact subjects such as mathematics (Mawaddah *et al.*, 2024). Intervention through a problem-based approach provides broader exploration space, builds meaningful connections to everyday life, and strengthens students' positive perceptions of learning (Winahyu *et al.*, 2024). This implication becomes even more relevant when linked to educators' efforts to foster new student motivation through contextual stimuli and authentic challenges.

Consistency of results is also evident in a recent meta-analysis demonstrating the effectiveness of problem-based learning in enhancing intrinsic motivation, learning satisfaction, and emotional engagement among students across various levels of education. Similar findings were found in research integrating PBL with interactive digital approaches, which also strengthened motivational outcomes in both online and face-to-face learning contexts (Budiningsih *et al.*, 2024). This empirical evidence strengthens PBL's position as a suitable learning model for fostering sustained motivation to learn mathematics among junior high school students.

CONCLUSION

The implementation of the PBL model has been shown to improve students' critical thinking skills and motivation to learn mathematics. The results of the study indicate that students who participated in learning with the PBL approach demonstrated better critical thinking skills and higher learning motivation compared to students who received direct learning. This model provides space for students to explore, reflect, and actively participate in solving mathematical problems contextually. Problem-based learning can accommodate a range of initial student abilities, thereby creating a more equitable and adaptive learning process. Therefore, this approach is recommended as a strategic alternative to improve the quality of mathematics learning, particularly by developing critical-thinking competencies and fostering sustained learning motivation.

AUTHOR'S NOTE

The author declares that there is no conflict of interest regarding the publication of this article. The author confirms that the article's data and content are free of plagiarism.

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