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Effect of Problem-Based Learning with Interactive Animation Videos on Math Problem-Solving and Critical Thinking Skills

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Abstract

This study aims to examine the effect of the Problem-Based Learning (PBL) model on students' mathematical problem-solving skills, considering their critical thinking abilities. A quasi-experimental design with a 2x2 treatment-by-level approach was used, involving two groups: one using the PBL model and the other using conventional methods. The subjects were seventh-grade students at SMP Negeri 6 Singaraja. Data were collected through tests on mathematical problem-solving and critical thinking abilities. The results show that the PBL model significantly affects mathematical problem-solving skills, particularly for students with high critical thinking abilities. Students in the PBL group had an average score of 79.9, higher than those in the conventional group, who scored 56.6 on average. Moreover, the interaction between the teaching model and critical thinking abilities significantly influenced the outcomes. However, for students with low critical thinking abilities, the PBL model did not have a significant impact on their mathematical problem-solving skills. This study concludes that the PBL model is effective in improving problem-solving skills in students with high critical thinking abilities but may need adjustments for students with lower critical thinking skills.

Keywords: Problem-Based Learning, Mathematical Problem-Solving Skills, Critical Thinking, Quasi-Experiment

INTRODUCTION

The Fourth Industrial Revolution (Industry 4.0) has brought significant changes to education, characterized by the integration of digital technology in every aspect of learning. This transformation enables learning to occur continuously, transcending spatial and temporal boundaries. In this era, education must align with the demands of Industry 4.0, emphasizing the development of skills that are crucial for the 21st century: creativity and innovation, critical thinking and problem-solving, communication, and collaboration (Lee et al., 2016). These skills, commonly referred to as the 4C, are essential for preparing students to face the challenges of the modern world.

In Indonesia, the government has taken steps to improve the quality of education through initiatives such as the Merdeka Curriculum. This curriculum seeks to cultivate creativity and innovation in students, encouraging them to engage more actively in the learning process and solve real-world problems (Suwardika et al., 2024). However, despite these efforts, challenges persist in mathematics education at the junior high school level.

One significant issue is the low level of students' problem-solving skills in mathematics. Many students struggle to apply their knowledge to real-life situations, limiting their ability to derive meaningful insights from the subject (Randeree, 2006). This challenge is often exacerbated by the continued use of conventional teaching methods that prioritize rote learning and teacher-centered instruction. Such methods fail to engage students meaningfully, leaving little room for the development of critical thinking or independent problem-solving skills (Karunanayaka et al., 2016).

Research has identified several barriers to students' mathematical problem-solving abilities. These include difficulties in understanding and applying concepts, analyzing problems, and following procedures. Additionally, factors such as lack of precision, limited time to solve problems, anxiety, and insufficient engagement contribute to these challenges. Addressing these issues requires innovative approaches that go beyond traditional teaching methods (Andriani et al., 2023).

One such approach is Problem-Based Learning (PBL), a model that centers learning around authentic problems. PBL encourages students to engage in critical, systematic, and creative thinking by solving problems rooted in real-life contexts. Studies have shown that PBL significantly improves students' critical thinking skills, making it a more effective alternative to conventional methods.

This study builds on the PBL framework by integrating interactive animated videos as a learning tool. These videos are designed to create a more engaging and dynamic learning experience, helping students visualize problems more clearly and develop critical thinking skills. By combining PBL with interactive media, this approach seeks to address the limitations of traditional teaching methods while fostering a deeper understanding of mathematical concepts.

Ultimately, this study aims to enhance students' problem-solving abilities and critical thinking skills in mathematics, preparing them to tackle complex challenges both in and out of the classroom. Through this innovative approach, students are expected to not only improve their mathematical proficiency but also develop a more positive attitude toward learning the subject.

This study aims to investigate the impact of the Problem-Based Learning (PBL) model on students' mathematical problem-solving abilities, considering their critical thinking skills. It also seeks to explore the interaction between the learning model (PBL and conventional models) and students' critical thinking abilities in influencing their mathematical problem-solving outcomes. This research is expected to contribute to the development of more effective teaching models, especially for students with high critical thinking skills, to enhance their mathematical learning outcomes. The novelty of this research lies in the application of the Problem-Based Learning model with interactive animation videos to improve students' mathematical problem-solving skills. Furthermore, it examines the interaction between the PBL model and students' critical thinking levels, a topic that has not been widely explored in previous studies. By linking critical thinking ability with problem-solving performance, this research fills a gap in the literature regarding how learning models affect students' individual critical thinking skills and mathematical problem-solving abilities. It aims to provide new insights into developing more inclusive and personalized teaching methods, particularly in the context of mathematics education.

Problem-Based Learning (PBL)

Problem-Based Learning (PBL) is a student-centered instructional model that emphasizes learning through solving real-world problems. According to Aprila et al (Aprila et al., 2023), PBL engages students in authentic problem-solving tasks that develop higher-order thinking skills, including critical and creative thinking. This approach fosters independent learning, collaboration, and the ability to apply knowledge in practical contexts. Through PBL, students actively construct knowledge by exploring problems, seeking solutions, and presenting their findings. This model is particularly effective in developing problem-solving skills as it aligns with the cognitive processes required to understand, analyze, and solve mathematical problems systematically (Gao et al., 2022).

Critical Thinking Skills

Critical thinking is the ability to analyze, evaluate, and synthesize information to make reasoned judgments and decisions. Yunita (2020) defines critical thinking as reflective and reasonable thinking focused on deciding what to believe or do. In the context of mathematics education, critical thinking is essential for interpreting problems, formulating strategies, and evaluating solutions. It encompasses skills such as interpretation, analysis, inference, explanation, and self-regulation. Developing critical thinking in students requires instructional strategies that encourage them to question assumptions, analyze data, and derive logical conclusions (Sulaiman & Azizah, 2020). This aligns with the goals of mathematics education to produce students who can think critically and solve complex problems effectively.

Interactive Animation Videos in Learning

The use of interactive animation videos in education provides a dynamic and engaging medium for delivering content. According to Dochy (2003), combining visual and auditory elements enhances learning by enabling students to process information more effectively. Interactive videos allow students to visualize abstract concepts, making them easier to understand and relate to real-world applications. In the context of Problem-Based Learning, interactive videos can serve as a powerful tool to present problems, guide students through exploration, and facilitate deeper comprehension. By integrating interactive media, educators can create a more engaging learning environment that stimulates students' interest and motivation to learn.

Mathematical Problem-Solving Skills

Mathematical problem-solving is a fundamental competency that involves understanding, analyzing, and resolving mathematical tasks. Mudrika (2024) outlines four key steps in problem-solving: understanding the problem, devising a plan, carrying out the plan, and reviewing the solution. These steps require a combination of critical thinking, logical reasoning, and creativity. The Merdeka Curriculum emphasizes problem-solving as a core objective of mathematics education, aiming to develop students' ability to connect mathematical concepts with real-world situations. Effective problem-solving instruction requires teaching models that promote exploration, reasoning, and reflection, enabling students to approach problems systematically and confidently.

METHODS

This study employs a quasi-experimental approach, a research method designed to investigate the effects of specific treatments on dependent variables under controlled conditions (Sugiyono, 2014). The research uses a treatment by level 2x2 design with a posttest-only control group. This design enables the simultaneous exploration of two independent variables learning models (Problem-Based Learning with interactive animation videos versus without them) and students' critical thinking levels (high and low) to assess their influence on students' mathematical problem-solving abilities. The chosen design assumes that each independent variable impacts the dependent variable individually, with the possibility of an interaction effect between them also contributing significantly to the outcome (Hardani et al., 2020).

The population for this study comprises all seventh-grade students at SMP Negeri 6 Singaraja. According to Syahza (2021), the population encompasses a generalization of research objects or subjects with distinct qualities and traits that researchers analyze to draw conclusions. Sugiarto (2022) further describes a population as a set of cases be it individuals, events, or phenomena that meet specific criteria determined by the researcher. The research will be conducted over a two-month period, from July to August 2024.

The sample is selected using a random sampling technique to ensure that every member of the population has an equal chance of being chosen, thereby minimizing selection bias and ensuring representativeness. This method facilitates unbiased selection while maintaining the reliability of the findings. Data collection instruments include a mathematical problem-solving test to measure students' performance after the intervention, a critical thinking assessment to categorize students, and observation sheets to document student engagement during the learning process.

The research procedure involves an initial categorization of students based on their critical thinking levels, followed by their random assignment to experimental and control groups. The experimental groups participate in Problem-Based Learning, with one group using interactive animation videos and the other not. After the intervention, a posttest is conducted to evaluate students' mathematical problem-solving abilities. The collected data are analyzed using a two-way ANOVA to assess the effects of the learning model, critical thinking levels, and their interaction, complemented by descriptive statistics to summarize performance trends.

Through this research, the study aims to contribute to the understanding of how Problem-Based Learning, enhanced with interactive animation videos, can improve students' mathematical problem-solving skills while accounting for variations in their critical thinking abilities.

RESULTS

Descriptive data

Descriptive data is presented to depict the data as it exists, according to the issues being researched. The data description is carried out for six different groups, namely: 1) students who participate in mathematics learning using the Problem-Based Learning (PBL) model with interactive animation videos (A1), 2) students who participate in mathematics learning using the conventional model (A2), 3) the group of students who participate in mathematics learning with the PBL model using interactive animation videos (A1) and have high critical thinking skills (A1B1), 4) the group of students who participate in mathematics learning with the PBL model using interactive animation videos (A1) and have low critical thinking skills (A1B2), 5) the group of students who participate in mathematics learning with the conventional model (A2) and have high critical thinking skills (A2B1), and 6) the group of students who participate in mathematics learning with the conventional model (A2) and have low critical thinking skills (A2B2).

Table 1. Descriptive data

	A1	A2	A1B1	A1B2	A2B1	A2B2
TOTAL	40	40	20	20	20	20
AVERAGE	69.7	56.3	79.9	58.65	56.6	56
STANDAR DEVIATION	20.4	20.3	16.5	19.2	25.06	14.9
MIN	25	20	40	25	20	30
MAX	100	95	100	95	95	90
SPANS	75	75	60	70	75	60
INTERVAL	6	6	2	2	2	2
FREKUENSI	12.5	12.5	30	35	37.5	30

Sources: Data Processed, 2024

Description

A1 : Data of 30 students participating in Mathematics Learning using the PBL Model assisted by Interactive Animation Video.

A2 : Data on students who take part in Mathematics learning using conventional models.

A1B1 : Data on Groups of Students who participated in Mathematics learning using the PBL Model assisted by Interactive Animation Video (A1) and had high critical thinking skills.

A1B2 : Data on Groups of Students who participated in Mathematics Learning Using the PBL Model assisted by Interactive Animation Videos (A1) and had low critical thinking skills.

A2B1 : Data on Groups of Students who participated in Mathematics Learning using a conventional model (A2) and had high critical thinking skills.

A2B2 : Data on Groups of Students who participated in Mathematics learning using the conventional model (A2) and had low critical thinking skills.

The data provides insights into the performance of students across six different groups, categorized based on the learning model used (PBL with interactive animation video vs. conventional) and their critical thinking abilities. Each group consists of 20 students, making the total sample size 120 students.

The A1 group, which used the PBL model with interactive animation videos, had an average score of 69.7, with a standard deviation of 20.4. The minimum score was 25, while the maximum score reached 100, giving a span of 75. The interval and frequency for this group were 6 and 12.5%, respectively. On the other hand, the A2 group, which used the conventional learning model, had a lower average score of 56.3 with a standard deviation of 20.3. This group also had a range of 75, with the highest score of 95 and the lowest score of 20. The interval and frequency for this group were also 6 and 12.5%.

When considering the A1B1 group (PBL with high critical thinking skills), the average score was 79.9, the highest among all groups. This group also had the lowest standard deviation of 16.5, indicating a more consistent performance. The score range was from 40 to 100, with a span of 60 and an interval of 2. The frequency for this group was 30%. Meanwhile, the A1B2 group (PBL with low critical thinking skills) had a slightly lower average score of 58.65, with a standard deviation of 19.2. The score range for this group was 70, with scores spanning from 25 to 95, and a frequency of 35%.

In the A2B1 group (conventional model with high critical thinking skills), the average score was 56.6, with the highest standard deviation of 25.06, indicating significant variability. The score range was 75, from 20 to 95, and the interval was 2 with a frequency of 37.5%. The A2B2 group (conventional model with low critical thinking skills) had the lowest average score of 56, with a standard deviation of 14.9, suggesting more consistency in performance compared to other groups. The score range was 60, with the lowest score being 30 and the highest score 90. This group also had a frequency of 30%.

Overall, the data shows that the PBL model with high critical thinking (A1B1) resulted in the highest average score and more consistent performance. In contrast, the conventional learning model (A2), especially with low critical thinking (A2B2), had the lowest average scores and more variability in student performance.

Normality Test

The normality test of the data distribution was conducted using the Liliefors formula. If the calculated L value (Lhitung) is smaller than the critical L value (Ltabel), the data is considered to follow a normal distribution. The criteria for the normality test state that if the resulting p-value is greater than 0.05, the data is normally distributed; if the p-value is less than 0.05, the data is not normally distributed (Candiasa, 2020). In this study, all the data were found to be normally distributed.

Hypothesis Test

Table 2. Hypothesis Test Result

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	2173,613	1	2173,613	5,822624	0,018231	3,96676
Columns	3631,513	1	3631,513	9,728014	0,002564	3,96676
Interaction	1930,612	1	1930,612	5,171681	0,02578	3,96676
Within	28371,15	76	373,3046			
Total	36106,89	79				

Sources: Data Processed, 2024

The table above presents the results of an analysis of variance (ANOVA) to examine the impact of different factors on a dependent variable. The analysis includes four sources of variation: Sample, Columns, Interaction, and Within. The sum of squares (SS) for each source indicates the total variation attributed to that factor, with the Sample having an SS of 2173.613, Columns having 3631.513, and Interaction having 1930.612, while the Within variation accounts for 28371.15. The degrees of freedom (df) for the sample, columns, and interaction are all 1, and for the within variation, it is 76, resulting in a total df of 79.

The mean square (MS) values, which are calculated by dividing the sum of squares by the respective degrees of freedom, show significant differences across factors. The F-statistics for Sample (5.822624), Columns (9.728014), and Interaction (5.171681) exceed the critical F-value (F crit = 3.96676), suggesting that these factors have a statistically significant effect. Furthermore, the P-values for all sources—Sample (0.018231), Columns (0.002564), and Interaction (0.02578)—are all less than 0.05, indicating that the differences observed are statistically significant. Therefore, the null hypothesis is rejected, and it can be concluded that Sample, Columns, and their Interaction have a significant impact on the outcome being studied.

DISCUSSION

The Effect of the Problem-Based Learning Model on the Level of Mathematical Problem-Solving Ability

The hypothesis test results show that learning with the Problem-Based Learning (PBL) model has a significant impact on the students' mathematical problem-solving abilities in grade VII. This is proven by the P-value or significance level of 0.0033, which is lower than the significance threshold of 0.05. Consequently, the null hypothesis (H0) is rejected, and the alternative hypothesis (H1) is accepted. This finding is further supported by the average problem-solving ability score of students who participated in the PBL model, which is 69.7, compared to 56.3 for those who participated in conventional learning.

The PBL model, supported by Interactive Animation Video, is a student-centered learning model. Students are presented with real-world problems, which encourages them to actively engage in analysis, thereby enhancing their thinking skills, problem-solving abilities, and intellectual capabilities. Furthermore, the PBL model is implemented in small groups, facilitating discussion and the exchange of ideas among students.

In contrast, conventional learning focuses primarily on the teacher, where the teacher provides concepts or information to the students. This teacher-centered approach often leads to passive learning, where students struggle to develop critical thinking skills. As a result, students may not fully comprehend the material, negatively impacting their learning outcomes. This aligns with the findings of Sajidan *et al* (2022), who observed that students taught using a problem-solving strategy in contextual learning performed better than those taught with conventional methods. In their research, it was found that students in problem-based learning environments achieved better learning outcomes because the learning was more meaningful, with students not only gaining information from textbooks but also from hands-on experiences.

Theoretically, the PBL model offers students the opportunity to improve various skills, such as critical thinking, finding and evaluating appropriate resources, teamwork in small groups, effective communication, and using contextual knowledge and skills for lifelong learning (Ghani et al., 2021). Additionally, the steps in problem-based learning direct students to think critically and understand concepts deeply (Asmiyunda & Hardeli, 2023). In the initial stage, students are presented with a problem to ignite their curiosity.

They are then divided into small groups to discuss and analyze the problem. The next stage involves the teacher encouraging students to gather data and conduct experiments until they fully comprehend the dimensions of the problem. The goal is for students to collect enough information to formulate their own ideas. Finally, students present their mathematical problem-solving results to their peers.

The Interaction Between the Learning Model and Students' Critical Thinking Abilities on Their Mathematical Problem-Solving Skills

The hypothesis testing results on the interaction effect indicate that there is a significant interaction between the learning model and students' critical thinking abilities in relation to their mathematical problem-solving skills. This is supported by a probability value (Sig) of 0.025, which is below the threshold of 0.05. The interaction shows that for students with high critical thinking skills, the Problem-Based Learning (PBL) model is more effective and positively influences their problem-solving abilities in mathematics.

PBL is an innovative learning model well-suited for the learning process, as it presents real-world problems that students must solve. By engaging with these problems, students are encouraged to actively construct their own knowledge through problem-solving activities. This approach helps students better understand the material and leads to improved learning outcomes. As they engage in solving real-life mathematical problems, students are not only applying their existing knowledge but also developing new insights through their reasoning and analysis.

Critical thinking skills also play a crucial role in determining students' mathematical problem-solving abilities. Students with strong critical thinking skills are able to: (1) identify and formulate problems, (2) provide logical arguments to justify their reasoning, (3) perform deduction, moving from general principles to specific conclusions, (4) apply induction to generalize from specific examples, (5) evaluate arguments critically, and (6) make decisions and take action to implement solutions. Such students are more likely to engage in reasoned thinking, making informed decisions and solving problems effectively. These skills not only enhance their academic performance but also empower them to tackle challenges in real life.

Southworth (2022), individuals with strong critical thinking abilities can present compelling reasons for their viewpoints, synthesizing conclusions from various premises and critically examining the relationships between different statements or data. This process is well-supported by the PBL model, where students are tasked with collecting and analyzing data related to mathematical problems. In this environment, critical thinking skills are essential for solving complex problems, making it a perfect fit for students who already possess strong reasoning abilities. In contrast, conventional teaching models, which focus on direct instruction, do not offer the same level of engagement and cognitive challenge (Utami et al., 2022).

In conclusion, the PBL model is highly effective for students with high critical thinking abilities. Its problem-solving approach fosters deep engagement, enabling students to process information and draw conclusions more efficiently. For instance, students with strong critical thinking skills will excel at making deductions and drawing inferences from mathematical problems, enhancing their ability to solve complex tasks. This interactive, inquiry-based model supports the development of higher-order thinking skills and has a positive impact on students' academic performance in mathematics.

The Effect of the Problem-Based Learning Model on the Mathematical Problem-Solving Ability of Students with High Critical Thinking Skills

The results of the third hypothesis test indicate that the Problem-Based Learning (PBL) model significantly affects the mathematical problem-solving abilities of students with high critical thinking skills. This is evident from the average score of 79.9 for students using the PBL model, which is considerably higher than the 56.6 average of students in the conventional learning model. Furthermore, the probability value (Sig) of 0.00078 is much lower than the significance level of 0.05, confirming the statistical significance of the result.

The PBL model, particularly when aided by interactive animation videos, is designed to help students develop their critical thinking, problem-solving, and intellectual skills. This model aligns with the process-oriented nature of mathematics, which involves understanding, analyzing, and solving problems, followed by drawing conclusions. When combined with critical thinking skills, this approach enables students to effectively identify, transform, and retain important information, which directly supports their ability to solve mathematical problems (Wiyaka et al., 2020).

The implications of this research suggest that the use of PBL can be particularly beneficial for students with strong critical thinking skills. By fostering an environment where students actively engage in problem-solving and critical analysis, PBL promotes a deeper understanding of mathematical concepts. The enhanced ability to solve mathematical problems also indicates a better grasp of the underlying principles, leading to more meaningful learning outcomes. This finding emphasizes the importance of incorporating PBL into educational practices, especially for students capable of high-level critical thinking, as it encourages active learning and prepares them for real-world problem-solving challenges.

The Effect of Problem Based Learning Model on the level of problem-solving ability of students who have Low Critical Thinking Skills

The results of the fourth hypothesis test indicate that the Problem-Based Learning (PBL) model does not significantly impact the mathematical problem-solving abilities of students with low critical thinking skills. This is supported by the probability value (Sig) of 0.525, which is higher than the significance level of 0.05. Although the average mathematical problem-solving score for students in the PBL group is 59.9, slightly higher than the 56 score for students using the conventional learning model, the difference is not statistically significant.

The primary reason for this lack of significant impact is the mismatch between the characteristics of students with low critical thinking skills and the nature of the PBL model. Students with lower critical thinking abilities generally struggle with organizing their thoughts and tackling complex problems (Launuru et al., 2021). They tend to feel more comfortable with conventional teaching methods that do not require active engagement or the solving of intricate, multi-step problems. In contrast, PBL demands higher levels of cognitive engagement and problem-solving, which these students may find challenging. As a result, their ability to construct knowledge is less effective in this context, limiting the benefits they derive from the model.

The implications of this finding suggest that while PBL is an effective model for students with high critical thinking skills, it may not be as suitable for those with lower critical thinking abilities. For students with lower critical thinking skills, more traditional and structured learning environments may be more beneficial, as they provide clearer guidance and less cognitive overload. Educators should consider using a combination of teaching methods, tailoring the approach to meet the varying needs of students, especially when working with those who struggle with critical thinking. This approach will help ensure that all students are provided with the support they need to succeed and develop their problem-solving abilities.

CONCLUSION

Based on the results of this study, it can be concluded that the Problem-Based Learning (PBL) model significantly influences students' mathematical problem-solving abilities, particularly for students with high critical thinking skills. PBL proves to be effective in improving mathematical problem-solving outcomes because of its approach, which emphasizes real-world problem-based learning that allows students to actively construct their own knowledge and develop critical thinking skills. However, the PBL model does not have a significant impact on students with low critical thinking skills, who tend to struggle with organizing their thoughts and solving complex problems. This suggests that this learning model is more suitable for students with high critical thinking skills, while for students with low critical thinking skills, conventional teaching methods may be more effective. The implications of this study highlight the importance of tailoring teaching methods to students' characteristics and needs in order to maximize their learning outcomes.

This study, while providing valuable insights into the effects of the Problem-Based Learning (PBL) model on students' mathematical problem-solving abilities, has certain limitations. First, the sample size used in the research was relatively small, as it only involved students from one school, which may limit the generalizability of the findings to a wider population. Additionally, the study focused on students from a specific grade level, which means the results may not apply to students at different educational stages. Another limitation is the short duration of the study, which lasted only two months, potentially affecting the long-term effectiveness of the PBL model. Furthermore, the study primarily concentrated on students' critical thinking abilities and mathematical problem-solving skills, without considering other factors such as students' motivation, learning styles, or prior knowledge, which could also influence the outcomes. Lastly, the research did not explore in depth how the implementation of PBL might vary across different teachers or classrooms, which could lead to different results based on teaching styles and classroom dynamics. These limitations suggest the need for further research with larger and more diverse samples, as well as a longer time frame, to better understand the broader implications of PBL in various educational settings.

Based on the findings and limitations of this study, several recommendations can be made for future research and educational practice. First, it is suggested that future studies expand the sample size and include schools from different regions or educational levels to enhance the generalizability of the results. A more diverse sample would provide a deeper understanding of how the Problem-Based Learning (PBL) model impacts students across various backgrounds. Additionally, future research should consider a longer study duration to observe the long-term effects of PBL on students' mathematical problem-solving skills and critical thinking abilities. Moreover, it would be beneficial to explore other factors, such as students' motivation, learning styles, and prior knowledge, which could influence the effectiveness of the PBL model. Further studies could also examine how different teaching approaches and teacher-student interactions influence the outcomes of PBL, as this may vary across classrooms. Finally, schools and educators should consider integrating Problem-Based Learning more widely, especially for students with high critical thinking abilities, as the results of this study suggest its effectiveness. However, for students with lower critical thinking skills, a more supportive approach or the combination of PBL with other teaching methods might be necessary to achieve optimal results.

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