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The Effect of Problem Based Learning Model Based on Problem Solving Strategy on Critical Thinking Ability

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Abstract
Physics instruction that relies solely on conventional learning models is one of the factors contributing to students' low critical thinking skills. This study aimed to examine the effect of the Problem-Based Learning (PBL) model based on a Problem-Solving Strategy on the critical thinking skills of eleventh-grade students at State Senior High School 2 Merauke in the topic of particle motion dynamics. This quantitative study employed a quasi-experimental research method using a pretest–posttest control group design. The sample consisted of class XI-4 as the experimental group and class XI-6 as the control group, selected through purposive sampling. The research procedure comprised three main stages: the preparatory stage (problem identification, literature review, development of instructional modules, and construction and validation of research instruments), the implementation stage (administration of the pretest, implementation of the intervention, and administration of the posttest), and the final stage (data analysis and formulation of conclusions). This study adopted Facione's indicators of critical thinking skills, based on their relevance and alignment with the operational definition of critical thinking employed in this research. The results showed that the experimental class achieved a higher percentage than the control class, demonstrating that the PBL model based on a Problem-Solving Strategy had a greater impact on improving critical thinking skills compared to conventional learning models.

Keywords: Critical Thinking Ability; Problem Based Learning; Problem Solving Strategy

INTRODUCTION

Education is one of the important elements in supporting national development by creating high-quality human resources. This is in line with the objectives of national education as stated in Law of the Republic of Indonesia Number 20 of 2003, Chapter II, Article 3, which states that "National education functions to develop capabilities and shape the character and civilization of a dignified nation in order to educate the life of the nation, and aims at developing the potential of learners so that they become human beings who believe in and are devoted to the One and Only God, possess noble character, are healthy, knowledgeable, competent, creative, independent, and become democratic and responsible citizens" (Nasional, 2003).

One of the subjects taught in senior high school education is Physics. Physics is a branch of science that is capable of developing students' logical thinking, critical thinking skills, and analytical abilities (Safitra, 2023). Physics is an important subject to be taught to students in order to equip them with the skills to think logically, analytically, systematically, critically, and creatively, as well as the ability to collaborate effectively (Saputra & Sukariasih, 2019). However, based on observations at one senior high school in Merauke, Physics learning activities still tend to be passive, with a focus on mastering physics formulas mathematically. The Physics teacher at the school also explained that there are still classes in which students have limited critical thinking abilities.

The physics learning process in senior high schools generally focuses only on aspects of knowledge comprehension, while synthesis, analysis, application, and evaluation are still insufficiently implemented. The learning materials used are oriented solely toward cognitive acquisition, so students only understand concepts but are unable to apply them to solve physics problems. This is one of the factors causing students to be unaccustomed to using their reasoning skills in problem solving, and as a result, their abilities have not developed optimally. Students are less capable of analyzing, synthesizing, and evaluating data, information, and opinions, so their critical thinking skills cannot develop properly. This condition is caused by learning activities that tend to always provide complete problem-solving procedures, resulting in students being unable to learn to solve problems independently using their own abilities.

Conventional learning models such as lectures, which are commonly implemented in schools, tend to make students passive during the learning process. Students merely receive the material delivered by the teacher and do not make full use of opportunities to ask questions and engage in discussions. Students' curiosity in seeking information remains low, which is an indicator of weak critical thinking skills. In physics learning, students need to develop reasoning and analytical abilities so that phenomena related to nature can be understood. According to Omosewo (1980), the most effective method to support students in the learning process is to connect them directly with objects or events related to the concepts being studied (Simbolon et al., 2017). One of the ways to address this is by implementing a Problem-Based Learning model based on a Problem-Solving Strategy. This approach requires analytical thinking skills such as formulating questions, analyzing, evaluating, and integrating information from various references in order to achieve deeper understanding and appropriate solutions (Minarti et al., 2023).

Problem-Based Learning is a learning model that utilizes real-world problems to acquire knowledge and make decisions by solving problems and engaging in critical thinking (Amin, 2017). This learning model presents real problems to students as an introduction to learning, which are then resolved through investigation and problem-solving approaches. In implementing the Problem-Based Learning model, teachers present problems to students and ask them to investigate and determine solutions independently, thereby encouraging students to be more actively involved in learning and to develop their critical thinking skills. The Problem-Based Learning model expects students to be directly involved in the research process. This model can enhance students' critical thinking skills in seeking and finding solutions to problems independently. There are three main objectives of the Problem-Based Learning model: to help students sharpen their investigative and problem-solving skills, to provide opportunities for them to learn from experience, and to enable students to develop critical thinking skills independently.

The Problem-Based Learning model consists of five phases: orienting students to the problem, organizing students for learning, guiding individual and group investigations, developing and presenting work results, and analyzing and evaluating the problem-solving process. According to Arends, Problem-Based Learning has several characteristics, including posing questions or real problems, focusing on interdisciplinary interaction, conducting real investigations, producing work and publications, and fostering collaboration (Trianto, 2009). The advantages of the Problem-Based Learning model include enabling students to understand concepts because they acquire that understanding independently, requiring critical thinking skills to solve problems, making learning more meaningful, presenting problems that reflect everyday challenges, fostering student independence, inspiring students, allowing them to give and receive others' perspectives, and facilitating interaction when students learn in groups (Pusparini et al., 2018).

Problem-Solving Strategy is a learning strategy that connects the material with problems in the surrounding environment. In this strategy, students are expected to solve physics problems according to their understanding. Problem-Solving Strategy has three principles: first, problem solving is an extension of learning activities, meaning that in exercising critical thinking, students must carry out several activities. The second principle is that learning activities aim to solve problems, positioning the problems as a medium for learning interaction. The third principle is that problem solving is conducted using logical reasoning methodologies. Problem-Solving Strategy involves four procedures: first, the generation stage, where students are trained to identify problems and determine the facts contained within them; second, the conceptualization stage, where students are trained to define the problems and develop strategic ideas to solve them; third, the optimization stage, where students are trained to select a strategy for solving the problem, evaluate the strategy, and plan the chosen solution; fourth, the implementation stage, where students are trained to implement the problem-solving plan and carry out the solution (Nikat, 2018).

The benefits of implementing a Problem-Solving Strategy in learning include enabling students to solve problems in accordance with the chosen steps, developing existing knowledge and acquiring new knowledge through case studies, utilizing laboratory tools related to the topics being studied, making use of available media, and applying analytical techniques; analyzing and describing, discussing the results of laboratory work or discussions in the form of written reports, diagrams, and oral presentations. Additionally, students work in groups by organizing each group effectively (Sunni et al., 2014).

Critical thinking ability is a systematic approach based on the principle that individuals can formulate and evaluate their own beliefs or ideas (Nuridayah et al., 2023). Critical thinking provides students with the opportunity to evaluate evidence related to the material and to recognize arguments that are invalid or irrational (Liska, Ahyo Ruhyanto, 2021). This study refers to the indicators of critical thinking according to Facione (2015), considering the alignment of these indicators with the definition of critical thinking ability used. Based on these indicators, the researcher analyzes students' critical thinking skills across several sub-skills, including interpretation, analysis, evaluation, inference, explanation, and self-regulation (Fithriyah et al., 2016). These critical thinking indicators are applied to the topic of particle motion dynamics, which includes several subtopics closely related to problems in the surrounding environment.

In essence, physics learning requires a model, strategy, or approach that can provide students with an understanding of concepts, mathematical procedures, and their applications in daily life. The context of learning through a Problem-Based Learning model based on a Problem-Solving Strategy emphasizes fostering students' logical and analytical thinking in addressing different conditions during problem orientation and systematically solving problems. Both teachers and students face certain limitations in implementing the steps of the Problem-Solving Strategy in physics learning. Previous studies conducted by several researchers have shown that Problem-Based Learning and Problem-Solving Strategy can improve critical thinking skills, analytical skills, and systematic reasoning skills (Lestari et al., 2019; Minarti et al., 2023; Nikat, 2018). However, the studies that have been conducted still separate Problem-Based Learning from the Problem-Solving Strategy. In this study, the researcher integrates the Problem-Solving Strategy into the stages of the Problem-Based Learning model to enhance students' critical thinking skills. Therefore, this study aims to examine the effect of a Problem-Based Learning model combined with a Problem-Solving Strategy on students' critical thinking skills in Merauke, specifically on the topic of Particle Motion Dynamics.

RESEARCH METHODS

Research Design

This study is a quantitative research using a quasi-experimental method with a pretest-posttest control group design. This method involves two classes: an experimental class and a control class. Both classes are given a pretest to assess students' initial abilities before the intervention. The experimental group receives an intervention in the form of a Problem-Based Learning model based on a Problem-

Solving Strategy, while the control group receives a conventional learning model intervention. After the learning models are implemented according to the respective class level, a posttest is conducted to compare the results of the two groups.

This study was conducted at SMA Negeri 2 Merauke. This study was conducted from January 13 to February 13, 2025, during the even semester of the 2024/2025 academic year, with activities carried out from preparation to the conclusion of the research.

Research Target/Subject

The population consists of all eleventh-grade students at SMA Negeri 2 Merauke in the 2024/2025 academic year. The sample consists of two classes: XI-4 as the experimental class and XI-6 as the control class. The sample was selected using a purposive sampling technique.

Research Procedure

The research procedure consists of three stages: the preparation stage (identifying the problem, conducting a literature review, preparing the module, and developing and testing the instruments), the implementation stage (pretest, providing the intervention, and posttest), and the final stage (data analysis and drawing conclusions).

Instruments, and Data Collection Techniques

The instruments used in this study are a critical thinking skills test and an observation sheet for the implementation of the learning model. The test is designed to measure the improvement of students' critical thinking skills in the topic of Particle Motion Dynamics. In this study, the test items for both the pretest and posttest are in the form of essay questions. The observation sheet used is for monitoring the implementation of the Problem-Based Learning model based on the Problem-Solving Strategy. In this study, the researcher refers to Facione's indicators of critical thinking skills, namely interpretation, analysis, evaluation, inference, explanation, and self-regulation, based on the consideration that these indicators align with the definition of critical thinking skills used.

Data analysis technique

The research instrument testing consists of validation, reliability testing, difficulty level testing, and discrimination power testing. The instrument validation conducted was a construct validity test using the Pearson product-moment correlation (Pearson, 1896).

$$r_{hitung} = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{[n \sum X^2 - (\sum X)^2].[n \sum Y - (\sum Y)^2]}}$$

Content validity was analyzed using the Content Validity Ratio (CVR) and the Content Validity Index (CVI). The formula for calculating the CVR value is as follows (Lawshe, 1975a).

$$CVR = \frac{n_e - \frac{N}{2}}{\frac{N}{2}}$$

After obtaining the CVR values, the CVI is calculated by dividing the total CVR by the number of validated items (Lawshe, 1975). The test items that have been tried out on students undergo reliability testing to measure the consistency of all essay questions using the Cronbach's Alpha formula (Arikunto, 2015). If r11 ≥ 0.40, the item is considered to provide consistent and reliable responses. Subsequently, the difficulty level test and the discrimination power test are conducted. Items with a discrimination index (D) ≥ 20 are considered capable of distinguishing students' abilities effectively.

The data analysis techniques used in this study include analysis of the implementation of the learning model, prerequisite tests (normality and homogeneity tests), hypothesis testing, and the percentage of critical thinking skills based on Facione's indicators. The implementation of the learning model was analyzed using the following formula (Handoko & Setiawan, 2023).

$$P = \frac{n}{N} \times 100\%$$

Normality testing was conducted using the Shapiro-Wilk analysis (Cahyono, 2015). If sig. > 0.05, the research data are considered normally distributed. This is followed by a homogeneity test. If sig. > 0.05, the research data are considered to come from identical variances (Sugiyono, 2013). If the prerequisite tests are met, hypothesis testing is conducted using parametric statistical analysis with a paired t-test; however, if the prerequisites are not met, hypothesis testing is conducted using non-parametric analysis, specifically Quade's ANCOVA. All analyses were assisted by SPSS Statistics 26, with a significance level of 0.05. Afterwards, the percentage of critical thinking skills based on indicators was analyzed using the following formula (Purwanto, 2010).

$$NP = \frac{R}{SM} \times 100$$

RESULTS AND DISCUSSION

Construct validity testing was conducted by two experts. The analysis of the construct validity test showed that 18 items were declared valid, while 2 items were declared invalid. Content validity testing was conducted by two subject matter experts to assess the items from the perspective of content or material. Based on the analysis results, 17 items were categorized as relevant, and 3 items were categorized as not relevant. The CVI for all items was 0.85, which falls into the "very appropriate" category. This indicates that the content of the analyzed items aligns well with the topic being studied. Therefore, 17 items were deemed suitable for use in the next stage.

The next stage involved a trial of the instrument with students who had completed the Particle Motion Dynamics learning. The trial consisted of 17 essay questions that had been declared valid and appropriate. The instrument trial was conducted in class XII-2 at SMA Negeri 2 Merauke with 29 students. The data from this instrument trial were used for reliability testing. The reliability test data came from the trial conducted in class XII-2 with 29 students. The reliability test results showed a value greater than 0.05, categorized as high. The reliability analysis results are presented in Table 1. The reliability test for the 17 items yielded a score of 0.627, categorized as "High." This indicates that the trialed items provide consistent results or answers, so the instrument has a high reliability value. This finding aligns with Arikunto (2015), who stated that an item is considered highly reliable if it can produce consistent results.

Table 1. The result of realibility test

Reliability Statistics		
Cronbach's Alpha	N of Items	Category
0.627	17	High

The trialed test items were then analyzed based on their difficulty level to ensure that the instrument had a balanced range of questions, from easy to difficult. This analysis used the data from the previous instrument trial. Based on the analysis, 2 items were categorized as easy, 12 items as moderate, and 3 items as difficult. Next, a discrimination analysis was conducted, showing that 11 items were considered valid, while the remaining 9 items were deemed invalid and discarded, making them unusable for the research stage. To assess an instrument's ability to classify students' abilities as high, medium, or low, a discrimination analysis was applied (Arikunto, 2015). The analysis results found 6 items categorized as good, 5 items as adequate, 4 items as poor, and 2 items as drop. This indicates that 11 items were able to classify students' abilities effectively, while the other 6 items could not differentiate students' critical thinking skills. The failure of certain items to distinguish critical thinking ability may be due to several factors. First, the items may have been too difficult or too easy, causing students to be unable to answer or resulting in similar answers from all students. Second, the wording or phrasing of the items may have been unclear, leading to misunderstandings and difficulty in solving the questions.

The implementation of the Problem-Based Learning model based on the Problem-Solving Strategy was assessed to provide an overview of the learning process, which was designed and implemented consistently in the experimental class throughout the learning period. This assessment was conducted by two observers, referring to the Problem-Based Learning syntax grounded in the Problem-Solving Strategy. The observation results indicated that the learning model was implemented effectively in each session. Data on the implementation of learning were obtained through observations of six sessions. Each syntax stage in the Problem-Based Learning model—problem orientation, organizing students for learning, guiding individual or group investigations, developing and presenting work, and analyzing and evaluating the problem-solving process—was carried out. Each stage of the Problem-Based Learning syntax was also based on the Problem-Solving Strategy. A summary of the observational data analysis is presented in Table 2.

Table 2. Recapitulation of the implementation of the problem-based learning model based on problem solving strategy

Meeting	Activity	Score Total	Percentage (%)	Note
1	Teacher	43	83	Very Good
	Students	40	77	Good
2	Teacher	42	81	Very Good
	Students	43	83	Very Good
3	Teacher	42	81	Very Good
	Students	38	73	Good
4	Teacher	44	85	Very Good
	Students	42	81	Very Good
5	Teacher	40	77	Good
	Students	41	79	Good
6	Teacher	40	77	Good
	Students	39	75	Good

The collected data were analyzed through prerequisite tests, including normality and homogeneity tests. The normality test results showed that the pretest scores in both the control and experimental classes had a sig. value of less than 0.05, while the posttest scores had a sig. value greater than 0.05. This indicates that the pretest scores in both classes were not normally distributed, whereas the posttest scores in both classes were normally distributed. The critical thinking skills data did not meet the requirements for using parametric statistical analysis. Therefore, the analysis used was the non-parametric Quade's ANCOVA. Quade's ANCOVA is applied when the assumption of conditional normality of the response variable is not met. Thus, the ranked ANCOVA method, specifically Quade's method, was used to test the hypothesis (Cangür et al., 2018). The normality test of the residual data showed a sig. value greater than 0.05, indicating that the residual data are normally distributed. The results of this test are presented in Table 43.

Table 3. The results of residual data normality test

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Residual for Posttest	0.077	64	0.200*	0.984	64	0.562

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Next, the homogeneity test results for both classes showed a sig. value greater than 0.05, indicating that the data came from identical variances. To perform Quade's ANCOVA analysis, the assumption of regression homogeneity is required. The regression homogeneity test results showed a significance value greater than 0.05, indicating that the posttest results were derived from a uniform variation. To meet the assumptions of Quade's ANCOVA, an analysis of regression slope homogeneity was conducted. The results of the regression slope homogeneity test showed a sig. value greater than

0.05. This indicates that the covariate regression with the dependent variable is uniform across each class.

The hypothesis in this study was analyzed using Quade's ANCOVA. Based on the hypothesis analysis, H_0 was rejected and H_a was accepted, indicating that the implementation of the Problem-Based Learning model based on the Problem-Solving Strategy has an effect on students' critical thinking skills. This aligns with findings from the literature, which show that the Problem-Based Learning model can enhance critical thinking skills, student engagement, and learning achievement (Minarti et al., 2023). By integrating the Problem-Solving Strategy into each stage of the problem-solving process, students are trained to develop their thinking skills. This demonstrates that the procedures developed in the Problem-Solving Strategy train thinking skills, analytical skills, and systematic reasoning skills (Nikat, 2018). The results of the hypothesis test are presented in Table 4.

Table 4. The result of hypothesis test

ANOVA					
	Unstandardized Residual				
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1484.882	1	1484.882	4.904	0.030
Within Groups	18773.795	62	302.803		
Total	20258.676	63			

The level of students' critical thinking skills can be determined based on essay test scores that reflect each critical thinking indicator. The percentage results of the pretest and posttest in the experimental and control groups indicate changes in their critical thinking abilities. The percentage increase in critical thinking skills from the pretest to the posttest for both classes is presented in Table 5.

Table 5. Percentage of critical thinking ability

Group	Average Percentage of Pretest (%)	Average Percentage of Posttest (%)	Improvement (%)
Control	25.13	35.80	10.67
Exp.	11.63	41.26	29.63

In the experimental class, students' critical thinking skills during the pretest were 11.63%, categorized as very low, while in the control class, the critical thinking skills were 25.13%, categorized as low. After the intervention was applied, a posttest was conducted, showing the impact of implementing the Problem-Based Learning model based on the Problem-Solving Strategy. The analysis of critical thinking skill percentages in the experimental class posttest showed 41.26%, categorized as sufficient, while the control class had 35.80%, categorized as low. The percentage increase in critical thinking skills from pretest to posttest was 29.63% in the experimental class and 10.67% in the control class. According to Pusparini (2017), the higher percentage in the experimental class indicates that the implementation of the Problem-Based Learning model based on the Problem-Solving Strategy has a greater effect compared to the conventional model applied in the control class.

Based on the analysis of posttest critical thinking skill percentages, some indicators showed significant and less significant changes. In the experimental class, three indicators were categorized as "sufficient," and three indicators as "low." The "sufficient" indicators included interpretation, explanation (explication), and self-regulation, while the "low" indicators included analysis, evaluation, and inference. This may be due to factors such as the limited duration of the study, constraints in implementing the learning model in the classroom, and students' learning motivation. This condition is supported by Dhina & Mubaroq (2017), who explained that to observe a consistent and valid improvement in students' critical thinking skills, at least three months of intensive study is required.

Some indicators still categorized as "low" can be attributed to specific conditions. For the analysis indicator, students may not yet be able to identify the relationships between concepts in a statement or question (Indiarti et al., 2022). For the evaluation indicator, some students may have limited skills in performing calculations and determining appropriate strategies to solve problems. For the inference indicator, some students may still have weak skills in connecting a problem with the solution obtained (Agnafia, 2019). Indicators that reached the "sufficient" category may also be influenced by certain conditions. For the interpretation indicator, it was categorized as "sufficient" because most students' ability to understand the material was fairly good. For the explanation (explication) indicator, most students had developed the skills to draw conclusions (Ariani, 2020). For the self-regulation indicator, it was due to students' high motivation to solve problems or overcome obstacles and their ability to control themselves and assess the results they produced (Andraini et al., 2021).

CONCLUSION

Based on the conducted study, the researcher found that the implementation of the Problem-Based Learning model based on the Problem-Solving Strategy has an effect on the critical thinking skills of 11th-grade students at SMA Negeri 2 Merauke. These results are supported by the higher percentage of critical thinking skill scores in the experimental class compared to the control class, indicating that the implementation of the Problem-Based Learning model integrated with a Problem-Solving Strategy has a greater effect on students' critical thinking skills than the conventional learning model. One contributing factor is the integration of the problem-solving strategy at each process offered in the stages of Problem-Based Learning, which trains students to develop thinking abilities, analytical skills, and systematic reasoning skills.

Several recommendations are proposed to improve the effectiveness of the Problem-Based Learning model based on the Problem-Solving Strategy. First, implementing this model requires a longer duration. Therefore, educators or future researchers should carefully manage time and materials to ensure that the applied syntax produces optimal effects. Second, during the learning process, one observed weakness was the lack of student enthusiasm in expressing opinions and ideas. Thus, students should be accustomed to interactive learning activities, such as group discussions or demonstrations/practicals involving active interaction among students and with the educator. Third, if future researchers want to implement the Problem-Based Learning model based on the Problem-Solving Strategy to enhance critical thinking skills, the study should be tested on more complex subjects to obtain more accurate and comprehensive information

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