The Effect of the Project Based Learning (PjBL) Model on Students' Critical Thinking Skills in Physics

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Abstract – *This study aims to examine the effect of the Project Based Learning (PjBL) model on students' critical thinking skills in physics, particularly on the topic of particle dynamics. This research employed a quasi-experimental method with a nonequivalent control group design. The population consisted of all eleventh-grade students of Senior High School 10 Mataram in the 2025/2026 academic year, totaling 53 students. The sample was selected using a saturated sampling technique, resulting in 28 students from class XI MIPA 1 as the experimental group and 25 students from class XI MIPA 2 as the control group. The experimental group was taught using the Project Based Learning (PjBL) model, while the control group received instruction through a conventional learning model. The results of the analysis showed that the average score of students' physics critical thinking skills in the experimental group was 78.57, which falls into the critical category, while the control group achieved an average score of 72.22, categorized as moderate. The instrument used to measure critical thinking skills consisted of six essay questions. Hypothesis testing was conducted using a pooled variance t-test with the criterion that if the calculated t-value exceeds the critical t-value, the alternative hypothesis is accepted and the null hypothesis is rejected. The t-test results indicated a calculated t-value of 2.29, which is greater than the critical t-value of 2.01 at a significance level of 5 percent. Furthermore, the N-Gain test was applied to determine the improvement in students' critical thinking skills. The results showed an N-Gain value of 0.68 for the experimental group and 0.57 for the control group, both of which fall into the moderate category. Based on these findings, it can be concluded that the Project Based Learning (PjBL) model has a significant effect on students' critical thinking skills in physics.*

Keywords: *Particle Dynamics; Critical Thinking Skills; Project-Based Learning*

INTRODUCTION

In the current era of globalization, the quality of human resources has become a decisive factor in a nation's ability to compete on the international stage. One of the most strategic efforts to ensure this quality is through the continuous improvement of educational standards. Indonesia is presently experiencing the effects of globalization, which significantly influence various aspects of life, including education. These demands can be addressed through the development of multiple competencies, such as knowledge, thinking skills, and other essential abilities (Syahputra, 2024). In the twenty-first century, science and technology serve as the primary foundation for national progress. Critical thinking, creativity, collaboration, and communication are key skills required for success in modern society. Therefore, school learning must be deliberately designed to equip students with the competencies needed to face future challenges (Rachmawati et al., 2018).

Despite its importance, attention to the development of critical thinking skills remains relatively limited, leaving substantial room for further exploration and enhancement. Several factors contribute to the underdevelopment of students' critical thinking skills, including low basic mathematical ability, limited learning motivation, minimal variation in instructional models, and insufficient use of problem types that foster critical thinking (Novalianti et al., 2021). Critical thinking skills must be continuously nurtured to

enable students to solve problems effectively and draw well-reasoned conclusions from various possible alternatives (Syafitri et al., 2021).

A learning model functions as a conceptual framework for designing, implementing, and evaluating the learning process (Rohmani et al., 2024). According to Rineksiane (2022), a learning model represents a comprehensive instructional design that encompasses the entire learning process from beginning to end and is implemented by educators. Based on these perspectives, a learning model can be defined as a conceptual framework that systematically guides the planning, execution, and evaluation of learning activities. An appropriate learning model can create a more effective, interactive, and student-centered learning environment that aligns with learners' needs.

Previous studies indicate that the implementation of the Project Based Learning model has a positive impact on the development of students' critical thinking skills, particularly in the context of twenty-first-century learning, which demands higher-order thinking abilities (Tendrita and Hidayati, 2023). Project Based Learning is generally defined as a student-centered instructional approach in which projects are used as a medium for understanding concepts or theories (Nuraini, 2023). This approach allows educators to manage classroom learning by actively involving students in project-based activities that promote meaningful learning experiences (Mahtumi et al., 2022).

The Project Based Learning model follows a structured sequence of activities, including problem definition, idea generation, discussion, prototype development, and sharing and testing outcomes (Busyairi et al., 2022). These stages provide clear guidance for educators in managing time, resources, and learning activities, ensuring that each project is conducted effectively and meaningfully. The systematic stages of Project Based Learning are designed to support both teachers and students throughout the project-based learning process. According to Dianawati (2022), these stages include formulating essential questions, designing the project, monitoring project implementation, completing the project and producing final outcomes, as well as conducting evaluation and reflection.

Critical thinking refers to the ability to search for, collect, analyze, and conceptualize information in order to enhance creativity in problem solving (Amalia et al., 2022). It is an essential skill that must be cultivated among students to enable them to address scientific concepts and problems effectively (Sulistyowarni et al., 2019). Critical thinking skills are particularly important for students to develop sound arguments, evaluate the credibility of information sources, and make well-informed decisions (Yusuf et al., 2022).

Project Based Learning plays a significant role in fostering students' critical thinking skills. Through project-integrated activities, students are encouraged to analyze problems, propose solutions, and draw conclusions independently, thereby strengthening their critical thinking abilities. This model is expected to enhance critical thinking by providing students with opportunities to engage in real-world problem-based projects, analyze relevant information, and discover solutions autonomously. Such learning experiences promote active participation and position students as the central agents in the learning process (Gunada et al., 2023).

Based on interviews conducted with physics teachers and students at SMA Negeri 10 Mataram, it can be concluded that

classroom instruction still predominantly relies on conventional teaching methods. This condition has contributed to the low level of students' critical thinking skills in understanding physics concepts. Therefore, instructional innovation is required, one of which involves implementing the Project Based Learning model. This model is expected to enhance students' critical thinking skills by engaging them in authentic problem-based projects, encouraging information analysis, and facilitating independent problem solving.

Although several previous studies have demonstrated the effectiveness of Project Based Learning in improving students' learning outcomes, research that specifically examines its impact on students' critical thinking skills remains limited. Furthermore, earlier studies have rarely analyzed improvements in critical thinking skills based on individual indicators. Accordingly, this study aims to analyze the effect of Project Based Learning on students' critical thinking skills by examining the extent to which the implementation of this model enhances those skills (Ratu et al., 2021). The findings of this study are expected to serve as a reference for educators in designing more effective instructional strategies to develop students' critical thinking skills, thereby preparing them to face future challenges more confidently.

REASERCH METHODS

This study employed a quasi-experimental research method with a nonequivalent control group design.

Table 1. Research Design

Group	*Pre-test*	Independent variable	*Post-test*
Experimental	O_1	X	O_2
Control	O_3	-	O_4

(Sugiyono, 2020)

The research population consisted of 53 eleventh-grade students of SMA Negeri 10 Mataram. The sample comprised 28 students from class XI MIPA 1 as the experimental group and 25 students from class XI MIPA 2 as the control group. The sample was selected using a purposive sampling technique. The research hypotheses were formulated as follows:

H_0 : There is no effect of the Project Based Learning (PjBL) model on students' critical thinking skills in physics.

H_a : There is an effect of the Project Based Learning (PjBL) model on students' critical thinking skills in physics.

This study involved three types of variables, namely independent, dependent, and control variables. The independent variable was the Project Based Learning (PjBL) model, while the dependent variable was students' critical thinking skills in physics. The control variables included learning content, instructional duration, teacher, learning environment, and students' characteristics. The research instrument was a critical thinking skills test consisting of six essay questions. The indicators of physics critical thinking skills referred to specific aspects used to measure students' ability to analyze, evaluate, and solve physics problems, as described in the study by Yeritia et al. (2017). The indicators applied in this study included interpretation, analysis, evaluation, inference, and explanation, as proposed by Facione (2011). Prior to implementation, the critical thinking test instrument was examined and confirmed to meet the requirements of validity and reliability.

Data analysis in this study included a normality test using the chi-square formula,

a homogeneity test using the Fisher F-test, and hypothesis testing using a pooled variance t-test to determine significant differences between the experimental and control groups. The testing criterion stated that if the calculated t-value exceeded the critical t-value, the alternative hypothesis was accepted and the null hypothesis was rejected. Conversely, if the calculated t-value was less than or equal to the critical t-value, the alternative hypothesis (H_a) was rejected and the null hypothesis (H_0) was accepted (Sugiyono, 2020). The analysis of critical thinking skills was conducted to examine the effect of implementing the Project Based Learning model on students' physics critical thinking skills. The classification of students' critical thinking skill levels is presented in Table 2.

Table 2. Critical thinking skills criteria

Score	Criteria
89-100	Very critical
78-89	Critical
64-78	Moderate
55-64	Low
0-55	Very Low

(Fitri, et al., 2023)

The N-Gain test was employed to determine whether there was an improvement in students' critical thinking skills. The criteria for interpreting the N-Gain values are presented in Table 3.

Table 3. Criteria of N-Gain Test

N-Gain score	Criteria
$g \geq 0.70$	High
$0.30 \leq g < 0.70$	Moderate
$g < 0.30$	Low

(Sukarelawan, et al., 2024)

RESULTS AND DISCUSSION

Results

This study was an experimental investigation conducted to examine the effect of the Project Based Learning (PjBL) model on the physics critical thinking skills of eleventh-grade students at SMA Negeri 10 Mataram in the 2024/2025 academic year. Two classes were selected as research samples, namely an experimental group and a control group. The experimental group received instruction using the Project Based Learning (PjBL) model, while the control group was taught using a conventional learning model.

Prior to the implementation of the study, the research instrument was tested on 30 students. The instrument consisted of an essay test comprising six questions, all of which had been tested and confirmed to meet the criteria of validity and reliability.

Based on the analysis of pre-test data, students' physics critical thinking skills were found to be at a very low level. This condition occurred because the students had not yet received instruction related to the tested material. Consequently, they relied solely on their prior knowledge when responding to the test items. This result is presented in Table 4.

Table 4. Pre-test results of critical thinking skills

Group	N	Lowest Score	Highest score	Average	Standard Deviation	Category
Experimental	28	11.11	50.00	31.55	11.42	Very Low
Control	25	11.11	66.67	33.78	14.34	Very Low

After the pre-test was administered, different instructional treatments were applied to the experimental and control groups. The experimental group was taught using the Project Based Learning (PjBL) model, while the control group received

instruction through a conventional learning model. At the end of the treatment period, a post-test was administered to both groups. The post-test analysis revealed an improvement in students' physics critical thinking skills, with the experimental group reaching the critical category and the control group achieving a moderate category. The post-test data for both the experimental and control groups are presented in Table 5.

Table 5. Post-test results of critical thinking skills

Group	N	Lowest Score	Highest score	Average	Standard Deviation	Category
Experimental	28	61.50	94.44	78.57	9.65	Critical
Control	25	50.00	88.89	72.22	10.64	Moderate

Prior to conducting hypothesis testing, prerequisite analyses were performed. These prerequisite tests included a normality test and a homogeneity test on the results of the physics critical thinking skills assessment. The results indicated that the data were normally distributed and homogeneous, demonstrating that the research data met the fundamental assumptions required for parametric statistical testing. The results of the normality and homogeneity tests for students' physics critical thinking skills are presented in Table 6.

Table 6. Results of the normality and homogeneity tests of critical thinking skills

Test	Group	N	χ^2_{calc}	χ^2_{table}	F_{calc}	F_{table}	Distribution	Variance
Pre-test	Experimental	28	6.24	11.07	1.57	1.93	Normal	Homogen
	Control	25	5.24					
Post-test	Experimental	28	4.13		1.22			
	Control	25	7.58					

Hypothesis testing was conducted to determine the effect of the Project Based Learning (PjBL) model on the critical thinking skills of students in the experimental group compared to those in the control group, who were taught using a conventional learning model. The hypothesis test was performed using the pooled variance t-test. The results of the t-test are presented in Table 7.

Table 7. Results of the hypothesis test of critical thinking skills

Group	S^2	t_{calc}	t_{tabel}
Experimental	93.07	2.29	2.01
Control	113.15		

The results of the study indicate that the Project Based Learning (PjBL) model has a significant effect on students' critical thinking skills in physics. As shown in Table 7, the calculated t-value exceeds the critical t-value, with a value of 2.29 compared to 2.01. The implementation of the PjBL model in the experimental group encouraged students to become more active, engaged, and enthusiastic in participating in physics learning activities, particularly in the topic of particle dynamics.

The improvement in students' critical thinking skills following the implementation of the Project Based Learning (PjBL) model was further analyzed using the N-Gain test. The results of this analysis are presented in Table 8.

Table 8. Results of the N-Gain test of critical thinking skills

Group	Criteria	*N-Gain*	Category
Experimental	Critical	0.68	Moderate
Control	Moderate	0.57	Moderate

Table 8 shows that the critical thinking skills of students in both groups fall within the moderate category. However, the level of improvement in the experimental group is higher than that in the control group, indicating that the application of the Project Based Learning model leads to a more substantial enhancement of students' critical thinking skills. To obtain a more detailed understanding of specific aspects of critical thinking, an indicator-based analysis was conducted to identify which indicators experienced the greatest improvement and which areas still require further reinforcement. The results of this analysis are presented in Figure 1.

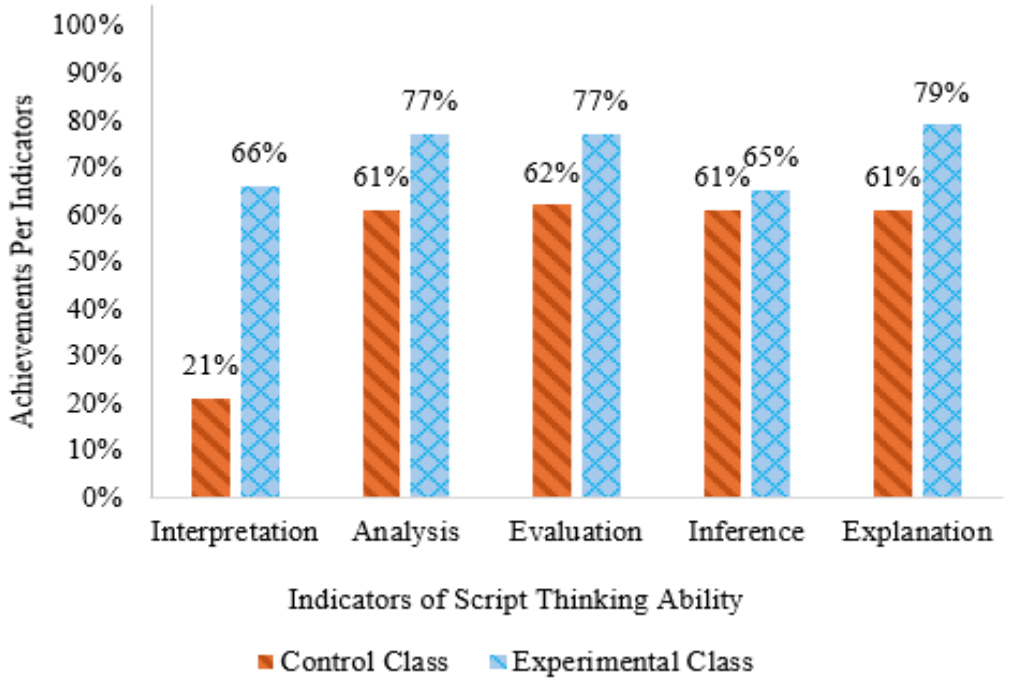

Figure 1. Comparison of N-Gain values of students' critical thinking skills between the control and experimental groups

Figure 1 illustrates a comparison of the percentage achievement for each indicator of students' physics critical thinking skills between the experimental and control groups. The results show that the experimental group achieved higher percentages across all critical thinking indicators compared to the control group. This finding suggests that the implementation of the Project Based Learning model contributes positively to the development of students' critical thinking skills in physics.

Discussion

Based on the analysis of the pre-test data, students' physics critical thinking skills were found to be at a very low level. The average score in the experimental group was 31.55, while the control group achieved an average score of 33.78. This condition occurred because students had not yet received instruction on the tested material and therefore relied solely on their prior knowledge when responding to the test items.

Following the pre-test, different instructional treatments were applied to the experimental and control groups. The experimental group was taught using the Project Based Learning (PjBL) model, while the control group received instruction through a conventional learning approach. A post-test was administered at the end of the treatment period. The post-test analysis revealed an improvement in students'

physics critical thinking skills, with the experimental group reaching the critical category and the control group remaining in the moderate category. The experimental group obtained an average score of 78.57, whereas the control group achieved an average score of 72.22. Although both groups showed improvement, a clear difference was observed between the two groups, indicating that the experimental group benefited more from the implementation of the Project Based Learning model than the control group did from conventional instruction.

Prior to hypothesis testing, prerequisite tests were conducted, including normality and homogeneity tests. These tests were essential to ensure that the collected data met the assumptions required for parametric statistical analysis. The normality test was performed to determine whether the pre-test and post-test scores of both groups were normally distributed, while the homogeneity test was conducted to examine whether the variances of the experimental and control groups were equal.

The results of the hypothesis testing indicate that the Project Based Learning (PjBL) model has a significant effect on students' physics critical thinking skills. As shown in Table 8, the calculated t-value was greater than the critical t-value, with 2.29 exceeding 2.01. These findings are supported by the study of Sholeh et al. (2024), which reported that the implementation of PjBL produces positive outcomes in enhancing students' critical thinking skills. This instructional approach effectively promotes active participation, encourages collaboration within groups, and increases students' confidence in expressing and defending their ideas.

Further analysis of the improvement in students' critical thinking skills following the implementation of the Project Based Learning model was conducted using the N-Gain test. The results showed that the experimental group achieved an N-Gain value of 0.68, categorized as moderate, while the control group obtained an N-Gain value of 0.57 in the same category. The higher improvement observed in the experimental group indicates that the Project Based Learning model is more effective in enhancing students' critical thinking skills than conventional instruction.

An indicator-based analysis revealed that the experimental group, which applied the PjBL model, demonstrated higher percentage achievements across all critical thinking indicators compared to the control group. This result indicates that the implementation of the PjBL model has a positive influence on the development of students' critical thinking skills. The highest achievement in the experimental group was observed in the explanation indicator, with a score of 79 percent, followed by the analysis and evaluation indicators, each with a score of 77 percent.

The explanation indicator is closely related to the project completion and final presentation stages, during which students are required to present their project outcomes. This process trains students to articulate ideas and provide logical reasoning clearly. High achievement in the analysis and evaluation indicators reflects the effectiveness of the project monitoring, evaluation, and reflection stages, as these phases require students to analyze information and address problems that arise during project implementation. This finding is consistent with the study by Gunada et al. (2023), which reported that project-integrated activities encourage active student participation and position learners at the center of the learning process.

Based on these findings, it can be concluded that the explanation indicator

plays the most influential role in improving students' critical thinking skills through the implementation of the Project Based Learning model. This outcome is attributed to the opportunities provided by project-based activities for students to actively communicate their ideas and project results, thereby fostering the development of critical thinking skills. The results of this study are in line with the findings of Suciani et al. (2018), who reported that the PjBL model is designed to develop students' critical thinking skills through active classroom engagement.

Sari and Angreni (2018) also stated that Project Based Learning directly involves students in the learning process to produce a tangible project. In this study, the projects developed by students on the topic of particle dynamics took the form of prototypes or simple devices created collaboratively in each learning session. These project products included a simple balloon-powered car, a miniature elevator, and a simple water wheel, as illustrated in Figure 2.

(a) (b) (c)

Figure 2. Project products developed by students, consisting of (a) a simple balloon-powered car, (b) a simple miniature elevator, and (c) a simple water wheel.

The development of these instructional tools provided students with meaningful and authentic learning experiences, as they were directly involved in the processes of designing and testing the devices. This hands-on activity encouraged students to practice critical thinking skills, including identifying problems, analyzing physics concepts relevant to everyday life, and evaluating the outcomes of the experiments conducted. In addition, the implementation of this learning model fostered collaborative skills, communication, and creativity, which are essential competencies in the twenty-first century (Rachmawati et al., 2018).

Based on the discussion above, it can be observed that students in the experimental group who were taught using the Project Based Learning (PjBL) model demonstrated stronger critical thinking skills than those in the control group who experienced conventional instruction. This outcome is closely related to the effective implementation of the Project Based Learning syntax. At the initial stage of learning, students in the experimental group were presented with real-world problems commonly encountered in daily life. These problems were provided through student worksheets, enabling learners to understand the given tasks more easily. This finding is supported by Mahtumi et al. (2022), who stated that project-based learning is an instructional approach that uses projects as the primary learning medium. Through this approach, students engage in exploration, assessment, interpretation, synthesis, and information processing to produce various learning outcomes.

CONCLUSION

Based on the research objectives, data analysis, and discussion, it can be concluded that the Project Based Learning (PjBL) model has a significant effect on students' critical thinking skills in physics. The products developed by students during the implementation of the PjBL model on the topic of particle dynamics, including a simple vehicle, a miniature elevator, and a simple water wheel, were effective in improving students' critical thinking skills to the critical category.

For future studies implementing the Project Based Learning model, it is recommended to design thematic projects that encompass all topics within particle dynamics and integrate digital technology. Such an approach would allow students to explore design alternatives, visualize abstract concepts, and perform interactive design iterations, thereby strengthening conceptual understanding and critical thinking skills within authentic learning contexts.

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