The Effect of STEAM-Based Project-Based Learning Model on the Critical Thinking Skills of Eleventh-Grade Students in the Topics of Elasticity and Hooke's Law

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Abstract *- Critical thinking skills must be possessed by students in order to face various problems. To enhance students' critical thinking abilities, a teaching model that can support these skills is needed. This study aims to examine the effect of the Project-Based Learning (PBL) model based on STEAM on students' physics critical thinking skills. The material used in this study is elasticity. This study explores the impact of the Project-Based Learning model as an independent variable on critical thinking skills as a dependent variable. The research method used is a quasi-experimental design with a non-equivalent control group design. The population of this study consists of all 159 students of class XI MIPA at MAN 1 Lombok Tengah. The sample used in this study includes class XI MIPA 5 as the experimental class and class XI MIPA 6 as the control class, selected using purposive sampling technique. Data analysis in this study was conducted using normality tests, homogeneity tests, and hypothesis testing. Based on the data analysis, the final results show that the average critical thinking score for the experimental class was 82.71, categorized as high, and for the control class was 72.96, categorized as medium. The research hypothesis was analyzed using the t-test for pooled variances. The obtained t-value was 5.54, and the t-table value was 1.706 at a 5% significance level. Therefore, since the t-value > t-table, the null hypothesis (H0) is rejected and the alternative hypothesis (Ha) is accepted. Based on the analysis results, it can be concluded that there is an effect of the Project-Based Learning model on students' physics critical thinking skills.*

Keywords*: Project-Based Learning; STEAM; Critical Thinking Skills*

INTRODUCTION

Education plays a crucial role in shaping students as human resources who are capable of thinking and behaving logically, analytically, systematically, critically, and creatively in solving problems. The students' cognitive abilities are closely linked to their learning activities, which can be applied to daily life (Rasnawati et al., 2019). The development of 21st-century education requires students to possess higher-order thinking skills (HOTS). The National Professional Certification Agency (BNSP) has worked to implement 21st-century education by shifting the learning process from being teacher-centered to being student-centered (Sumardiana, 2022).

According to Wangi (2022), critical thinking ability is a way to convey concepts by asking profound questions about the information received, allowing the truth to be objectively discovered. This skill helps students through the analysis process and towards finding solutions. Students with adequate critical thinking skills tend to be able to tackle challenges systematically, formulate innovative questions, and generate creative solutions to various problems.

The application of the Project-Based Learning (PBL) model is an innovative learning method that encourages students to think critically and actively engage, producing a product from the project they undertake

at the end of their studies. Students can explore through project activities and be directly involved in the process of creating a product (Sulastri, 2021). According to Dewi et al. (2023), project-based learning has several advantages, including increasing students' motivation to learn, developing cooperative and collaborative skills, boosting creativity, and enhancing students' communication skills. In this context, students are expected to collaborate with others, thus improving problem-solving, resource management, and coordination. Moreover, project-based learning can also create a pleasant learning environment.

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Science, Technology, Engineering, Arts, and Mathematics (STEAM) is a project-based learning approach that integrates five disciplines: science, technology, engineering, arts, and mathematics. STEAM education can increase students' curiosity and motivation in problem-solving, teamwork, and project-based learning (Mu'minah, 2020). The application of STEAM in education allows students to explore their creative potential and provides opportunities to address challenges. Through STEAM projects, students can become more adept at applying knowledge to create solutions or products (Mu'minah, 2021).

Based on a questionnaire filled out by 22 students, it was found that students' interest in physics learning is still lacking, with some perceiving physics as a relatively complicated subject that is difficult to remember and understand. According to data provided by the teacher, this is reflected in the low average scores on the midterm exams (PTS) for physics, which are below the Minimum Completion Criteria (MCC), as shown in Table 1.1.

Tabel 1. Result of PTS for XI MIPA MAN 1 Lombok Tengah

Group	Number of Students	Average score	MCC
XI IPA 1	39	70	75
XI IPA 2	40	72	75
XI IPA 3	38	72,60	75
XI IPA 4	37	62,40	75
XI IPA 5	41	68,40	75
XI IPA 6	38	65	75

(Source: Physics Teacher of MAN 1 Lombok Tengah)

Based on observations conducted on February 12, 2024, several challenges were identified in the learning process. One of the issues is that many students perceive physics as difficult because it requires understanding numerous formulas, leading to a lack of interest and focus during lessons. Additionally, the teaching process is still teacher-centered, relying heavily on lectures and question-and-answer sessions, with limited use of learning media.

The Project-Based Learning (PBL) model has not been implemented, resulting in insufficient development of students' critical thinking skills. To address these issues, an appropriate learning model is needed. According to Ridha (2022), the STEAM-based Project-Based Learning model is an educational approach in which students engage in project-based activities to solve specific problems. STEAM-based

project-based learning can enhance collaboration, communication, and foster critical thinking skills among students.

The implementation of STEAM offers numerous benefits for students. Through STEAM education, students can improve collaboration, creativity, communication, and critical thinking. The STEAM approach also encourages students to explore social and emotional aspects, allowing them to not only excel academically but also develop their creative potential and gain opportunities to tackle real-world problems (Subiki, 2023).

RESEARCH METHODS

This study uses a quasi-experimental design involving two groups: an experimental group and a control group. The experimental group receives treatment using the project-based learning model, while the control group is treated with the conventional teaching model. The research design is illustrated in Table 2.

Table 2. Research Design

Group	Pre-Test	Treatment	Post-Test
Experimental	0_1	×	0_2
Control	0_3	–	0_4

(Sugiyono, 2016)

Description:

O1 : Administration of a pretest to the experimental class before the project-based learning model is implemented

O2 : Administration of a posttest to the experimental class after receiving instruction with the project-based learning model.

O3 : Administration of a pretest to the control class before receiving instruction with the conventional teaching model.

O4 : Administration of a posttest to the control class after receiving instruction with the conventional teaching model.

X : Instruction in the experimental class using the project-based learning model.

This study employs the Non-equivalent Control Group Design method, where the research subjects are not randomly assigned to the experimental and control groups. The sampling technique used is purposive sampling, in which the researcher makes a deliberate decision in selecting the sample. The instruments used include learning tools such as the syllabus, lesson plans (RPP), teaching materials, learning media, Student Activity Sheets (LKPD), and instruments for assessing critical thinking skills.

Data analysis in this study includes tests for homogeneity, normality, and hypothesis testing. The homogeneity test is used to determine whether the two groups are homogeneous. The normality test is used to determine whether the test data is normally distributed. In this study, the normality test is calculated using the Chi-squared formula (Sugiyono, 2017). The hypothesis test is conducted to determine whether there is an effect of the STEAM-based project-based learning model on students' critical thinking skills in physics, using a t-test for pooled variance.

The steps used in the STEAM-based project-based learning model are as follows:

1. **Starting the lesson with a question**: This step incorporates the science component of STEAM, where students study the theoretical foundation of the material to be learned.
2. **Planning the project**: This step includes the technology component of STEAM. In this phase, students are divided into groups to plan the creation of a project, and they can use smartphones to search for relevant information related to the project.

3. **Creating a schedule**: In this step, students create a schedule for the stages of the project, from preparation to presentation.
4. **Monitoring project development**: This step includes the engineering and arts components of STEAM. In this phase, the teacher guides students through the experiments according to the project plan that was discussed within their groups.
5. **Assessment of the produced product**: This step incorporates the mathematics component of STEAM, where students calculate the results of the experiments they have conducted.
6. **Evaluation**: In the final step, both the teacher and students evaluate the learning activities that have been carried out.

RESULTS AND DISCUSSION

Results

a. Data of Results

The research data on students' critical thinking skills consists of pretest and posttest data. The pretest data is used to assess the initial condition of students' critical thinking skills, which will be used as the sample in this study. This data is also used to determine the homogeneity and normality of students' critical thinking skills. The pretest results for the experimental class show an average score of 51.81, with the highest score of 70 and the lowest score of 65. For the control class, the average score is 51.50, with the highest score of 65 and the lowest score of 35. Based on the pretest results, it can be concluded that the initial critical thinking skills of the students in both classes are not significantly different and are relatively similar. The pretest data can be seen in Table 3.

Table 3. Result for Pre-test of Critical Thinking Skill

Group	Min Score	Max Score	Average Score
Experimental	40	70	51,81
Control	35	65	51,50

The final data, or posttest results, represent the data obtained after the treatment was applied to both the experimental and control groups. This final data will also be used to test the hypothesis presented in the study through hypothesis testing. Before conducting the hypothesis test, the data will first undergo normality and homogeneity tests as prerequisites.

For the experimental group, the average posttest score was 82.17, with the highest score being 95 and the lowest score being 72.5. In contrast, the posttest data for the control group showed an average score of 72.96, with the highest score being 85 and the lowest score being 62.5.

Based on the final data, it can be observed that there was an improvement in the average posttest scores compared to the pretest scores in both the experimental and control groups. The posttest data can be viewed in Table 4.

Table 4. Result for Post-test of Critical Thinking Skills

Group	Min Score	Max Score	Average Score
Experimental	72,5	95	82,17
Control	62,5	85	72,96

The graph depicting the average critical thinking test scores obtained from the pretest and posttest of the students in the experimental and control groups can be seen in Figure 1.

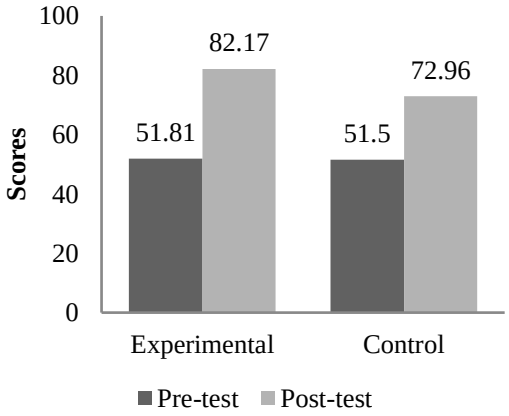

Figure 1. Diagram Average score for pre-test & post-test of critical thinking

b. Normality Test

The normality test is one of the prerequisite tests for conducting hypothesis testing. This test is performed to determine whether the obtained data follows a normal distribution. The results of the normality test for the experimental and control groups can be seen in Table 5.

Table 5. Normality Test for *Pre-test*

Group	X^2_{count}	X^2_{table}	Description
Experimental	3,15	11,070	Normal Distributed
Control	7,39	11,070	

From the results of the normality test for the pretest, the calculated Chi-square values were 7.39 for the control group and 3.15 for the experimental group, both of which are smaller than the table Chi-square value of 11.070. According to the decision rule, if the calculated Chi-square value is smaller than the table value, the data is considered normally distributed. Based on this data and a significance level of 5%, it can be concluded that the data follows a normal distribution.

The results of the normality test for the posttest indicate the same outcome, with the data also being normally distributed. This can be seen in Table 6.

Table 6. Normality Test for *post-test*

Group	X^2_{count}	X^2_{table}	Description
Experimental	10,6	11,070	Normal Distributed
Control	4,32	11,070	

c. Homogeneity test

The Homogeneity test is conducted to determine whether the experimental group and the control group are homogeneous. If the results of the homogeneity test indicate that the data is homogeneous, it means that both groups have similar abilities. The data tested for homogeneity are the final or posttest data.

For the results of the homogeneity test for the pretest and posttest data in both the control and experimental groups, the table value of F was 1.689, which is greater than the calculated F value of 1.130 for the pretest. According to the decision rule, if the table F value is greater than the calculated F value, the data is considered homogeneous. For the posttest, the calculated F value was 1.266, which is smaller than the table F value of 1.689, indicating that the posttest data is homogeneous.

Based on the results of the homogeneity test, it can be concluded that the data is homogeneous. The results of the homogeneity tests can be seen in Tables 7 and 8.

Table 7. Homogeneity test for pre-test of critical thinking skills

Group	$\bar{x}$	F_{count}	F_{table}	Desc.
Experimental	51,81	1,130	1,689	Homogeneous
Control	51,50			

Table 8. Homogeneity test for post-test of critical thinking skills

Group	$\bar{x}$	F_{count}	F_{table}	Desc.
Experimental	82,17			Homogeneous
Control	72,96	1,130	1,689	

d. Hypothesis Test

After the prerequisite tests, the next step is to conduct the hypothesis test. The data tested are the posttest results. This test is carried out to determine whether there is an effect from the treatment applied, in this case, the use of a problem-based learning model, on the critical thinking skills of students regarding the topic of vibrations and waves.

The results of the hypothesis test can be seen in Table 9.

Table 9. The results of the hypothesis test

Group	Average Score	t_{count}	t_{table}	Desc.
Experimental Control	82,17 72,96	5,54	1,706	Hypothesis Accepted

Based on the table, it shows that there is a difference in the average post-test scores between the experimental and control classes. The results of the t-test indicate that Ha is accepted because $t_{count} > t_{table}$. Therefore, there is an effect of the project-based learning model on students' critical thinking skills in physics.

The improvement in students' critical thinking skills can be seen in Figure 2.

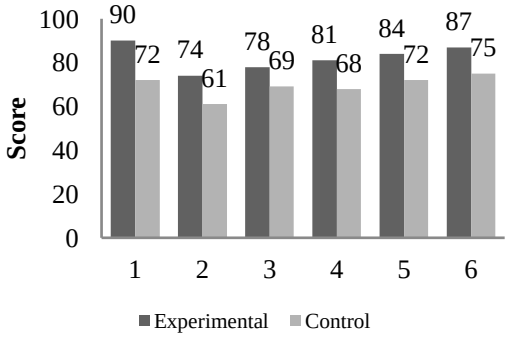

Figure 2. Score for each indicator of critical thinking skill

Discussion

This study aims to identify the effect of the STEAM-based Project-Based Learning (PjBL) model on students' critical thinking skills in physics. The STEAM-based PjBL model was applied in the experimental class, XI MIPA 5, while conventional learning was applied in the control class, X MIPA 6. Both classes consisted of 36 students. The research was conducted over three meetings with the topics of elasticity and Hooke's law. Both classes were given a pretest to assess their initial knowledge before the treatment. After the treatment, both classes took a posttest to evaluate students' critical thinking skills. The pretest was conducted in both classes to ensure that both groups started with similar conditions. The average pretest score for the experimental class was 51.81, and for the control class, it was 51.50, both categorized as low. Afterward, the two classes were treated differently: the experimental class used the PjBL model based on STEAM, while the control class received conventional teaching. After the treatment, both classes took a posttest. The average posttest score for the experimental class was 82.71, categorized as high, while the control class had an average posttest score of 72.96, categorized as medium.

The results showed that the experimental class, which used the PjBL model based on STEAM, demonstrated higher critical thinking skills compared to the control class, which used conventional learning. In the experimental class, students became more active, interested, happy, and enthusiastic during the learning process. This was supported by the successful implementation of the PjBL model and STEAM-based activities. The relationship between the project-based learning model and critical thinking skills can be seen through the critical thinking indicators used. During the

learning process, student activity increased, with students understanding concepts better and completing projects independently while collaborating with their teams to solve problems. The PjBL model during practical activities improved students' critical thinking skills, as they were able to identify problems, which encouraged them to think critically to solve a project. Through the integration of the PjBL model based on STEAM, students had the opportunity to explore ideas, produce a product, and enhance their critical thinking skills. The application of the STEAM approach in the project of creating a simple spring balance involves several key aspects. First, in the science field, students learn the basics of Hooke's law and how springs work. Next, in technology, students use smartphones to search for relevant information. In engineering, students design and assemble a simple spring balance in groups. Subsequently, in Art, students create an engaging poster explaining the spring balance and the results of the experiment. Finally, in mathematics, students calculate the spring constant based on the results of their experiments. This helps students understand the concept deeply and apply it in real-world situations, which is the essence of critical thinking. Thus, the STEAM-based PjBL model model can enhance students' critical thinking abilities and create a more active learning environment.

The results of this study align with previous research by Sumardiana et al. (2019), which concluded that the Project-Based Learning model is a process-oriented model, relatively time-consuming, focused on problems and disciplines, and teaches students to be more active in developing creativity through project-based problem-solving, which enhances skills such as observing, using tools, interpreting, planning projects, applying concepts, and effective communication. This study also supports the findings of Nurjanah et al. (2023), who found that the PjBL-STEAM model is effective in improving critical thinking skills because each stage of learning requires teamwork, communication, problem-solving skills, and responsibility. Additionally, this study is in line with the research by Ansumarwaty et al. (2023), which found that the Project-Based Learning model provides students with opportunities to engage with the material through problem-solving projects, thus improving their critical thinking skills.

CONCLUSION

Based on the results of the research and discussion as outlined, it can be concluded that there is an influence of the STEAM-based project-based learning model on the critical thinking skills of the students at MAN 1 Lombok Tengah. The validity and reliability tests of the instruments show that all the questions used are valid and reliable. The pre-test results indicate that the initial critical thinking skills of the students in both the experimental and control groups are homogeneous and normally distributed. After the implementation of the STEAM-based project-based learning model, the post-test results showed a significant improvement in the critical thinking skills of the students in the experimental group compared to the control group. This indicates that the STEAM-based PjBL model is effective in enhancing the students' critical thinking skills. The hypothesis test confirmed that there is a significant difference between the experimental and control groups, supporting the hypothesis that the STEAM-based PjBL model has a

positive impact on students' critical thinking skills.

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