The Effect of PjBL on Critical Thinking Skills of High School Students in Physics Learning on Topic of Static Fluid

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Abstract - *In the 21st century, students are required to possess a variety of skills to face the challenges of the times, one of which is critical thinking. Educational activities, including physics instruction, serve as an important medium for fostering these skills. However, physics is often perceived as a challenging subject, primarily due to the dominance of teacher-centered learning models. This highlights the need for student-centered approaches that actively engage learners in the educational process. One such approach is the Project-Based Learning (PjBL) model. This study aims to examine the effect of the PjBL model on students' critical thinking skills in physics learning, specifically on the topic of static fluids. The hypotheses tested in this study are: H_0 (there is no significant effect of the PjBL model on students' critical thinking skills) and H_a (the PjBL model has a significant effect on students' critical thinking skills). The research employs a quasi-experimental design with a control group. The population consists of Grade XI students at SMA IT Abu Hurairah Putri, Mataram City. A saturated sampling technique was used, with class XI MIPA 1 assigned as the experimental group and XI MIPA 2 as the control group. The research instrument was a critical thinking test comprising four questions, all of which were previously validated and proven reliable. Data analysis was conducted using the Mann-Whitney U test at a 5% significance level. The results indicate a p-value of 0.001, which is less than the threshold of 0.05. Thus, the null hypothesis (H_0) is rejected, leading to the conclusion that the PjBL model has a significant effect on students' critical thinking skills.*

Keywords*: Project Based Learning; Critical Thinking Skills; Static Fluid*

INTRODUCTION

The challenges of life at this time require students to master various aspects of learning. The important aspects that student need to master in current learning activities are summarized in the 21st century skills needs. These skills include: creative thinking, critical thinking, problem solving skills, communication and collaboration (Hamzah, 2023).

Critical thinking is an ability that focuses on the ability to decide what to believe or do through a reflective thinking process (Zakiah and Ika, 2019). Critical thinking skills are the ability to analyze, evaluate, and make decisions based on available information in a logical and rational manner (Sari and Lutfi, 2023). This ability can help students evaluate the information obtained and develop solutions with arguments that can be accounted for (Saepuloh, et al., 2021). Emily R. Lai in Zakiah and Ika (2019) states that critical thinking skills have the following characteristics: analyze arguments, make conclusions, assess/evaluate, and make decisions or solve problems.

Critical thinking skills are a necessity for everyone. Therefore, improving critical thinking skills should be presented in the learning process (Zakiah and Ika, 2019). Educators have long realized the importance of this skill as a result of the learning process of students (Wahyudi, et al., 2019), including in physics learning. However, physics learning is considered a difficult learning for students (Vuztasari and Diyana, 2024).

Difficulties in understanding learning, including physics, are caused by the application of inappropriate learning models (Setyaningsih, et al., 2024). The formal learning process still applies conventional models like teacher centered (Parwati, et al., 2020; 'Ardhuha, et al., 2022). This causes problems in learning because students do not play an active role in the learning process (student centered) (Sahida, 2020).

The use of an appropriate learning model is one of the efforts that can be made to overcome the problem of difficulties in understanding physics learning (Wahyudi, 2021). One of the learning models that can be applied is the project-based learning (PjBL) model (Hutasoit, 2021). Through this model, students are trained to analyze problems, provide critical responses, find solutions, and provide different learning experiences (Dywan and Gamaliel, 2020). This is in line with various previous studies that have been conducted.

Research conducted by Hasani *et al.* (2024) showed that the application of the PjBL model was also proven to improve the critical thinking skills of high school students. The results of other studies also state that the application of the PjBL model in teaching can prepare students in facing the complexity of the modern world. PjBL not only improves academic grades but important life skills for students (Wulandari, et al., 2024). Therefore, this model is expected to improve students' critical thinking skills with the following syntax: (1) fundamental questions and project determination; (2) design of project completion steps, (3) preparation of project implementation schedule, (4) project completion facilitated by teacher monitoring, (5) preparation of project reports and presentations/publications, (6) process evaluation of project results (Kementerian Pendidikan dan Kebudayaan, 2018).

Although previous studies showed PjBL improves thinking skills, little is known about it's effectiveness in physics topics such as static fluids, especially in the Indonesian context. However, different research result have been also conducted by Astuti et al. (2023) which compared the effectiveness of the PjBL model with other model (PBL). It was found that the application of PjBL did not provide a significant increase in students' critical thinking skills compared to PBL. Therefore, researchers are interested in conducting research on this matter.

Based on the description that has been presented, this study aims to determine whether or not there is an effect of the application of the PjBL model in improving the critical thinking skills of students in physics learning, especially in static fluid material. The indicators used in measuring critical thinking variables in this study are: (1) the ability to analyze, (2) the ability to evaluate, and (3) the ability to argue further. (Susilowati and Sumaji, 2020).

RESEARCH METHODS

This research is a quasi-experimental design using a control group design in the form of using an experimental class and a control class. The population in this study were grade XI students at SMA IT Abu Hurairah Putri Mataram City. Sampling was carried out using saturated sampling technique with XI MIPA 1 as the experimental and XI MIPA 2 as the control class. Students will be given an initial test and final test in both classes, experimental and control, without random assignment (Sugiyono, 2019). The experimental group will be given treatment in the form of learning using the PjBL model, while the

control group uses a conventional model (Table 1).

The instrument used in this research is a test instrument in the form of a description question consisting of 4 questions. The instrument has been tested for validity and reliability. The results of instrument testing found that all questions have valid and reliable categories.

Table 1. Research design

Group	Initial test	Treatment	Final test
Experiment	O_1	X	O_2
Control	O_3		O_4

Description:

O_1 : Giving an initial test to the experimental class

O_2 : Giving the final test to the experimental class

O_3 : Giving an initial test to the control class

O_4 : Giving the final test to the control class

X : Giving treatment to the experimental class using the PjBL model

The data obtained is used to determine the level of critical thinking ability of students. The categories used for critical thinking variables can be seen in Table 2.

Table 2. Categories of critical thinking skills

Score	category
81,26 < value≤ 100	Very Critical
62,51 < value≤ 81,25	Critical
43,76 < value≤ 62,50	Critical Enough
25,01 < value≤ 43,75	Less Critical
00,00 < value≤ 25,00	Very Less Critical

(Kurniahtunnisa, et al., 2024)

The data obtained were processed using the Jamovi statistical application by first testing for their normality and homogeneity. Normality test was conducted using Shapiro Wilk p. If the *p value* obtained > 0.05 then the data is declared normal, and vice versa (Mukherjee and Pratham, 2025). While the homogeneity test was carried out using the F test. If $F_{count} < F_{table}$, the data is declared homogeneous, and vice versa (Gokpinar & Gokpinar, 2021). If the assumptions of homogeneity and normality are met, hypothesis testing is continued with the ANOVA parametric statistical test. If not met, hypothesis testing is carried out using a non-parametric statistical test, the Mann Whitney U test. The test is carried out to determine whether or not there is an effect of giving treatment in the form of applying the PjBL model on students' critical thinking skills.

Hypothesis testing is carried out by applying a significance level of 5% and paying attention to the *p value of* each test (Susilawati, *et al*., 2025). If the *p value* < *0*.05, then H_0 is rejected so that is stated there is an effect of the application of the PjBL model on students' critical thinking skills. Meanwhile, if the *p value* > *0*.05 then H_0 is accepted so that it is stated that there is no significant effect of the application of the PjBL model on the critical thinking skills of students.

RESULTS AND DISCUSSION

Results

Based on the research that has been conducted, the initial test data of the critical thinking skills of experimental and control class students can be seen in Table 3.

Table 3. Initial test of critical thinking skills

Group	N	Lowest Score	Highest Score	Average
Experiment	23	0	30	7,61
Control	23	0	33	9,39

The initial test was then tested for normality and homogeneity with the results listed in Table 4 and Table 5.

Table 4. Normality test results of the initial test of critical thinking skills

Class	N	Shapiro-Wilk p (*p value*)	Description
Experiment	23	0,884	Normally distributed
Control	23	0,012	Not normally distributed

Table 5. Homogeneity test results of the initial test of critical thinking skills

Class	F_{count}	F_{table}	Description
Experiment Control	1,06	2,05	Homogeneous

The summary of the final test data of students' critical thinking skills can be seen in Table 6 below.

Table 6. Final test of critical thinking skills

Class	Highest Score	Lowest Score	Average
Experiment	95	2	33
Control	91	0	55

Based on the table above, the average value of the final test of the control class is higher than the experimental class. The final test was then tested for normality and homogeneity with the results in Table 7 and Table 8.

Table 7. Normality test results of the final test of critical thinking skills

Class	Shapiro-Wilk p (*p value*)	Description
Experiment	0,013	Not normally distributed
Control	0,075	Normally distributed

Table 8. Homogeneity test results of the final test of critical thinking ability

Class	F_{count}	F_{table}	Description
Experiment Control	0,73	2,05	Homogeneous

The test was then continued using the Mann Whitney U statistical test because the normality assumption was not met. The results of the Mann-Whitney U test analysis of the final data on students' critical thinking skills are presented in Table 9. The data in the table obtained *p value* < 0.001 which shows that there is a significant difference between the critical thinking skills of the experimental and control classes.

Table 9. Hypothesis testing results

Value	Statistics (U)	*P value*
Mann-Whitney U	117	0,001

The critical thinking variable used in this study has 3 indicator points in the form of (1) analysis, (2) evaluation, and (3) further argumentation. Each question on the test instrument has these three indicators. To find out the value of each indicator, the value of each indicator for each question is summed up and converted, so can be compared on a scale of 1-100. The comparison diagram of the final test scores of the experimental class and control class can be seen in Figure 1 and Fgure 2.

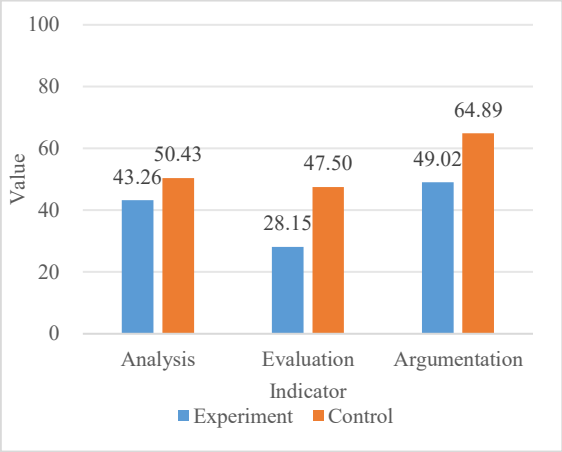

Figure 1. Average score for each class

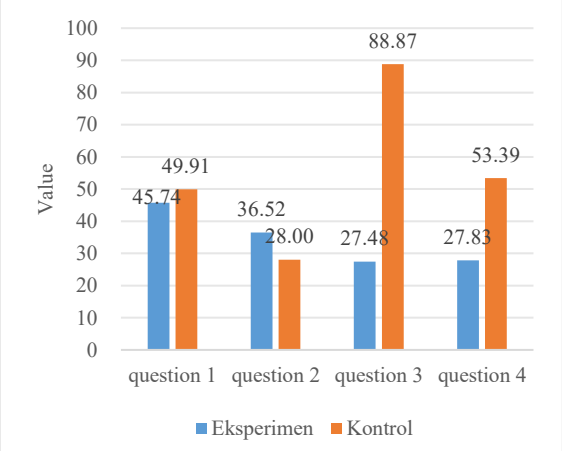

Figure 2. Bar chart of average final test scores for each question.

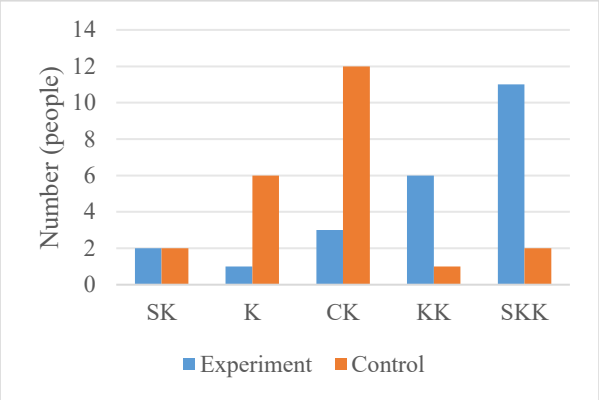

Figure 3. Bar diagram of the category of students' critical thinking level.

Description:
SK : Very Critical
K : Critical
CK : Critical Enough
KK : Less Critical
SKK : Very Less Critical

Based on the results of the data from the test results of students' critical thinking skills, it was found that the majority of control class students had critical thinking skills in the moderately critical category. While the majority of students in the experimental class had a category of less critical to very less critical (Figure 3).

Discussion

The application of the PjBL model begins with asking fundamental questions and determining the project that students do, namely making a simple hydraulic jack. Through this project, students are invited to analyze the relationship between pressure, force, and cross sectional area according to the principle of Pascal's Law, evaluate the performance of the tools made, and formulate arguments based on observations and experimental results. In addition, they also face the real situations that require problem solving and decision making, which is the core of the critical thinking process.

Students' critical thinking skills, in the form of analyzing skills, are trained to determine the equations and concepts used and the variables involved in the designed project. Students then discuss the results of their analysis with the groups that have been distributed.

After analyzing, students are asked to determine the design of the project work steps along with the work schedule. The design and schedule that has been prepared then presented. The agreed design is then used as the basis for the project.

Students then work on the project that has been given for several days. During the second meeting, the teacher conducted the monitoring stage while facilitating students who had problems in working on their projects. Students are trained to think critically by evaluating the project being worked on. The evaluation is in the form of trying to collect and calculate data on the project they are working on, analyzing problems and how to solve these problems, to determining problems that need to be consulted with the teacher.

The results of the project (Figure 4) that students have made are then presented at the third meeting. At this stage, students are trained to argue about the results of the project. Both the successes and obstacles experienced are based on scientific explanations.

Figure 4. One of the students' project works: a simple hydraulic jack.

The final stage of project work is the evaluation of the project that has been done. Students evaluate each other's projects in the form of submitting questions, criticisms, and suggestions for each group. Followed by an evaluation from the teacher regarding the application of concepts to the general work process.

Based on the research that has been conducted, the average results of the initial test of students' critical thinking skills between the control class and the experimental class show that the control class and the experimental class have a relatively comparable value comparison (Table 3). While the results of the data on the average value of the final test of students' critical thinking skills in the experimental class were obtained at 33 and the control class at 55 (Table 6). The control class final test score data is higher than the experimental class. The results in Figure 3 also show that the data on the level of critical thinking skills of control class students is higher than the experimental class. This shows that the learning method used in the control class is more suitable for solving mathematical problems with elements of critical thinking of students.

When viewed from the critical thinking indicators used, the control class obtained higher scores than the experimental class on each indicator (Figure 1). Likewise, if a review is carried out based on the question items (Figure 2), the results show that the majority of control classes get higher scores than experimental classes. This can be caused by the level of difficulty of projects undertaken by students that are not in accordance with the need to improve critical thinking skills. These results are in line with research conducted by Riyadi et al. (2020) which showed that there was no significant difference between the experimental and control groups in the application of the PjBL model to improve critical thinking skills. This is partly due to the implementation of the PjBL model which emphasizes the completion of projects rather than deep thinking processes to improve critical thinking skills, which also happened in this study.

In addition to being too focused on the project, the lack of complexity of the concepts used in the project can also have an effect (Riyadi, et al., 2020). The lack of complexity of the project causes the lack of analysis and evaluation skills of students. Therefore, the complexity of the project should be considered in the application of the PjBL model.

Based on Table 9, the results show that there is an influence between the provision of different treatments on students' critical thinking skills. The Mann Whitney U test results show a p value of $0.001 < 0.05$. Thus, statistically, it can be concluded that there is an effect of the PjBL model on critical thinking skills.

Although the statistical results show the influence of the PjBL model on critical thinking skills, the researcher assumes that this influence is not a positive influence where PjBL can improve students' critical thinking skills. This is based on the results of the final test scores of the control class which are higher than the experimental class (Table 6).

The average results of students' critical thnking skills in the experimental class were actually lower than the control class. This result shown that although there's a significant difference between the two groups, the direction of the difference has not shown the superiority of PjBL model in improving students' critical thinking skils over conventional model, in the context of this research. This caused by the statistial test used in this research, Mann Whitney U test, technically only tests wheter or not

there's a significant difference between two groups, but doesn't directly indicate the direction of influence (positive or negative) of the treatment given. Data analysis with non parametric test still has limitations inshowing the direction and manitude of the effect. Therefore, interpretation of the results needs to also refer to descriptive data such as mean and median scores.

Based on the data on the average value of the control class which is higher than the experimental class, it can be concluded that the application of the PjBL model doesn't have a positive effect on the students' critical thinking skills. This can be caused by several factors, such as (1) the limited time for implementing the PjBL model; (2) the level of project complexity that has not fully triggered optimal critical thinking involvement; (3) the character of students who are more accustomed to the direct learning system. Linearity of project difficulty can also affect the results. Projects should further trigger students' critical thinking skills.

Altough the simple hydraulic jack project was planned to improve the critical thinking skills, in this application, this project still didn't trigger students to think more deeply in accordance with the principles of PjBL which emphasizes deep learning. This due to the relatively short project work time, causing not many aspect can be explored more deeply.

A similar study to this research was conducted by Hasani et al (2023) with conflicting results, PjBL has a positive effect on the critical thinking skills of high school students in physics learning. In this research, students were asked to make a prototype project of a simple elasticity measuring device. In addition to using the PjBL model, STEAM elements were also applied to the learning process. In contrast to this research, which only relies on the application of the PjBL model without any collaboration with other elements. This indicates that the application of PjBL can be more effective when associated with the use of other elements and media as support.

In addition to the things mentioned above, other factors are also thought to influence the results of this research. These factors include the readiness of the learners in accepting the learning model. Therefore, the application of a new learning model takes time to be accepted.

The results in this study are in line with research by Astuti et al. (2023) which compared the effectiveness of the PjBL model with PBL. As a result, the application of PjBL did not provide a significant increase in students' critical thinking skills compared to PBL. Furthermore, Telaumbanua (2024) who also examined the effect of PjBL on students' critical thinking skills found that there was no significant difference between groups using PjBL and PBL. Factors such as students readiness and classroom management were stated to influence these results. Based on the results of this study, it can be concluded that the application of the PjBL model is not always effective in improving critical thinking skills.

CONCLUSION

Based on the results of the research and discussion, it can be concluded that there is an influence of the PjBL learning model on the critical thinking skills of high school students in physics learning, especially static fluid material. However, the influence given is not always positive. Although the statistical results show that there is an effect, it has not been proven to be effective in practice. We recommend that the application of the project-based learning model be carried out by paying attention to several things such as: (1) the readiness of students

in implementing project-based models; (2) a longer time allocation (long-term) than other models; (3) the level of difficulty and depth of concepts in the applied project needs to be linear with the abilities expected to emerge; (4) incorporation with additional elements (like STEAM) or other methods to improve the effectiveness of the PjBL models.

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