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# Implementation of Case-Based Learning to Improve Critical Thinking Skills in Static Fluids among High School Students

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**Abstract:**

This study aimed to examine the effectiveness of implementing the Case-Based Learning (CBL) model in enhancing students' critical thinking skills in static fluid learning, as well as to analyse differences in critical thinking outcomes between classes using CBL and those employing conventional teaching methods. The research adopted a quasi-experimental design with a pretest–posttest control group. Samples were selected based on simple random sampling. After the data was analysed, the average score of critical thinking skills for the experimental class was 72.74 which was classified as good, and 60.18 for the control class, which was classified as the enough category. Furthermore, the results showed that the p-value was less than 0.000, indicating a significant difference in critical thinking skills between the experimental and control groups. These results suggest that the CBL model is effective in improving students' critical thinking skills.

## 1. Introduction

National development is strongly influenced by its education system and its ability to respond to societal and technological changes (Wahyudi, 2022). In this era of rapid development of science and technology, it is essential to master 21st-century skills, namely the 6C, including critical thinking skills (Ichsan et al., 2020). In line with this, Regulation of the Minister of National Education of the Republic of Indonesia No. 20 of 2016 emphasizes the importance of developing students' critical thinking skills to enable them to address complex problems and make logical and responsible decisions (Khoerunisa & Habibh, 2020).

PISA in 2018 noted that out of 79 countries that participated in the assessment, Indonesia was ranked 71st in science literacy, which is closely related to critical thinking skills (Hewi & Shaleh, 2020). The 2022 PISA report again shows the same pattern, where Indonesia occupies the 68th position out of 81 participating countries (Siregar et al., 2024). This condition is largely attributed to learning approaches that remain one-directional and teacher-centered, so it does not encourage student exploration (Mayasari et al., 2016). In addition, critical thinking skills are also not optimally developed because the subject matter is often presented without being associated with the real-life context (Sari et al., 2021). This condition shows that the mastery of critical thinking skills in science learning, especially physics, is still a problem that needs serious attention.

In response to these conditions, Regulation of the Minister of Education and Culture (Permendikbud) No. 24 of 2013 highlights the importance of fostering students' critical thinking skills by positioning teachers as facilitators who promote active student engagement in the learning process (Ariyanto et al., 2020). Consistent with this policy, the implementation of Case-Based Learning (CBL) supports the development of critical thinking skills by encouraging students to conduct in-depth analyses of specific events or problems and engage in discussions to formulate alternative solutions (Muaffiani et al., 2022).

CBL represents a relevant instructional approach for addressing these challenges (Fatimah & Nurita, 2023). The primary advantage of the CBL model lies in its potential to enhance students' critical thinking skills (Nizam & Partiwi, 2023). This learning model integrates well-documented, real-world case studies derived from everyday experiences as the primary pedagogical foundation for the teaching and learning process (Dayu et al., 2022). With these characteristics, the case-based learning model has the potential to be a relevant learning model to overcome students' low critical thinking skills in physics learning.

The physics teacher at SMA Negeri 15 Pekanbaru explained in an interview that the learning method used in this dive is a combination of lectures and discussions. As a result, learning focuses more on the teacher's formulas and explanations, making it less likely for students to relate the material to real-life situations. This condition affects critical thinking skills that have not been developed and have never been systematically measured. Static fluid is one of the most crucial materials. However, students often encounter difficulties and misconceptions when mastering these concepts (Rosdiana et al., 2019).

The difficulties experienced by students in learning the concept of static fluids can be found in several subtopics of static fluids, such as the assumption made by students that hydrostatic pressure is influenced by the liquid or the shape of the container rather than by the depth or density of the liquid (Berek et al., 2016). Understanding static fluid concepts requires critical thinking, particularly when analyzing their application in real-world situations.

Several reviews of research on the implementation of the CBL indicate an improvement in students' critical thinking skills. However, research regarding the application of the CBL specifically to static fluid topics remains limited. Therefore, this study aims to examine the influence of the CBL model on students' critical thinking skills within the context of static fluids.

Accordingly, the objectives of this research are:

1. To evaluate the effectiveness of implementing the CBL in enhancing students' critical thinking skills during static fluid lessons.
2. To analyse the differences in critical thinking skills between classes utilizing CBL and those applying conventional learning methods.

This article contributes to the establishment of CBL as a viable approach for learning environments that do not require complex technological infrastructure. This application is particularly relevant for schools with limited facilities or restricted access to educational technology. Furthermore, this study emphasizes the importance of designing contextual cases as a bridge to help students relate physics concepts to real-world situations. Given these characteristics, CBL can be implemented more broadly across various educational contexts as an effective learning strategy.

## 2. Theoretical Framework

### *2.1. Learning Model Case Case-Based Learning*

Case-Based Learning (CBL) is a learning model rooted in the theory of constructivism, where students are faced with various forms of cases as the core of the learning process (Dayu et al., 2022). CBL itself is a learning model that is not only interesting and effective, but also able to provide greater challenges for students as they solve the questions presented in a case format (Asfar et al., 2019).

According to Syarafina et al (2017) the CBL has several main characteristics that are the foundation of its application, namely (1) cases, (2) study questions, (3) small group work, (4) class group discussions, and (5) follow-up activities. Similar to other learning models, CBL also involves a series of systematic stages that must be passed from start to finish. According to Williams (2005), adapted from Maastricht, the stages of case-based learning are illustrated in Figure 1.

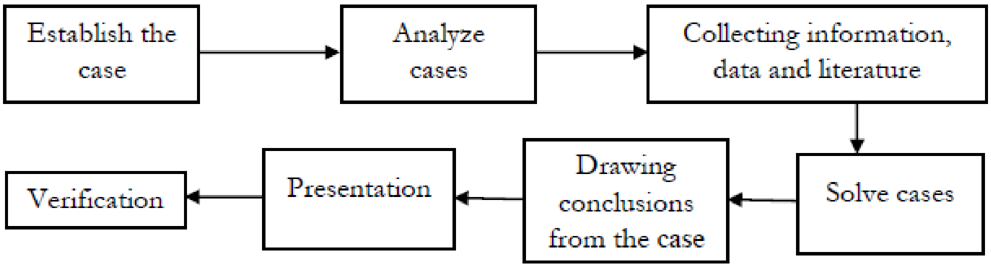


**Figure 1.** *Steps of the case-based learning model*

Trianto in (Minarni et al., 2025) explained that the CBL has several advantages including (1) students' skills to express issues or cases and relate them to new situations, (2) the development of analysis, collaboration, and communication skills, (3) increased students' active involvement in the learning process, and (4) honing cooperative, communicative, and critical thinking skills. Nevertheless Dewi & Hamid (2015) also outlines some of the weaknesses of CBL, including (1) students can experience difficulties in solving cases if they lack confidence, (2) the need for careful planning at the beginning of learning, including the selection of the right cases, and (3) not all subject matter is suitable to be applied using this learning model.

### *2.2. Critical Thinking Skills*

A person's ability to process and assess information objectively, enabling them to make appropriate and practical decisions, is referred to as critical thinking skills. According to Indriana (2019), there are several important reasons why students are required to have this skill, namely (1) to help achieve in-depth understanding, (2) to support the analysis of the thinking process when writing, to solve problems, to make decisions, and to evaluate the data received, (3) to enable students to choose logical and reasonable solutions, and (4) to be a means to assess effectiveness through the development of mental aspects.

One of the figures in the field of critical thinking, Ennis, stated that this skill includes five main aspects, namely (1) basic clarification, (2) based for a decision, (3) advanced clarification, (4) supposition and integration, and (5) inferences (Ennis, 2011). According to Nkhoma et al. (2016), there are three hypotheses of cognitive development from critical thinking, namely application of knowledge improves case analysis skills, case analysis strengthens evaluative assessment skills, and evaluative assessments support creative solution generation skills.

## 3. Method

### *3.1. Types of Research*

This study employs a quantitative quasi-experimental design with a pretest–posttest control group structure. This design was selected because: (1) the research was conducted in a natural setting where full randomization was not feasible as class schedules could not be altered; (2) it allows the researcher to measure changes in the dependent variable before and after the treatment; (3) the inclusion of a control group, also measured via pretest and posttest, helps control for several threats to internal validity; and (4) the research results are expected to have high practical application as they closely approximate actual field conditions.

The CBL treatment in this study is operationalized through mechanisms that explicitly activate the dimensions of students' critical thinking skills. The "case establishment" stage focuses on basic clarification, specifically by addressing questions, analysing arguments, and asking and answering questions. Furthermore, the "case analysis" stage focuses on the elementary basis for decision-making, particularly assessing the credibility of sources. Subsequently, the "information, data, and literature gathering" stage activate advanced clarification, where students learn to define terms, evaluate definitions, and identify unstated assumptions. The "solve case" process develops the ability to formulate suppositions and integrate information through the requirement to formulate hypotheses and synthesize obtained data. Ultimately, the "drawing conclusions and presentation" stage reinforces the inference aspect, including performing and evaluating deductions, as well as making and assessing value judgments. Additionally, the "verification" stage also trains inference through material inference. Through this operationalization, the CBL treatment functions as an intervention that activates critical thinking indicators. The research design is presented in Table 1.

**Table 1.** *Pretest design and posttest control group design*

| Class | Pretest | Treatment | Posttest |
|---|---|---|---|
| Experiment | $0_1$ | X | $0_2$ |
| Control | $0_3$ | - | $0_4$ |

## *3.2. Population and Sample*

This study involved students as research subjects. All research activities were approved by the school and carried out without disrupting the learning process. Student participation was conducted with the consent of teachers, and student identities and data were kept confidential and used only for research purposes.

The 142 students of grade XI Physics at SMA Negeri 15 Pekanbaru form a population, divided across four classes. Before determining the experimental and control classes, all classes in the population underwent prerequisite tests, including normality and homogeneity tests, using data from previous daily test scores to ensure that the research sample was drawn from a normally distributed and homogeneous population. The results of this population were obtained from Class $XI_C$, comprising 35 students in the experimental class, and Class $XI_D$, comprising 34 students in the control class.

## *3.3. Data Collection Procedure*

The research procedure began with a pretest consisting of a 17-item multiple-choice test. This test was administered to students in both the experimental and control classes to measure their critical thinking skills prior to the learning treatment. Before the pretest was conducted, the researcher informed participants about the study, including its objectives, stages of activities, benefits, potential risks, data confidentiality guarantees, and their right to refuse or withdraw participation at any time without academic consequences.

Subsequently, the CBL was implemented in class XIC as the experimental group, while class XID served as the control group using conventional learning. Lessons were conducted in their respective classrooms over three sessions, with learning steps adapted to the Kurikulum Merdeka teaching modules. In the experimental class, learning followed the CBL stages, utilizing case-based student worksheets (LKPD) completed in groups during each session. Meanwhile, in the control class, learning was conducted conventionally through lectures, class discussions, and practice problems related to the subject matter.

Upon completion of the entire learning process, a posttest was administered using the same instrument as the pretest. This test was given to both the experimental and control classes to measure the students' critical thinking skills following the implementation of the learning treatments.

The data obtained from the pretest and posttest results were analysed using descriptive and inferential statistics. Prior to hypothesis testing, prerequisite tests were conducted, specifically the normality test using the Kolmogorov–Smirnov method and the homogeneity of variance test using Levene's Test.

## 3.4. Research Instrument

**Table 2.** *Critical thinking skills test instrument grid*

| No. | Aspect | Indicators | NQ |
|---|---|---|---|
| 1 | Basic clarification | 1. Focus on a question | 1 |
| | | 2. Analyse arguments | 2 |
| | | 3. Ask and answer questions | 2 |
| 2 | Based for a decision | 4. Judge the credibility of a source | 2 |
| | | 5. Observe, and judge observation reports | 1 |
| 3 | Advance clarification | 6. Define terms and judge definitions | 1 |
| | | 7. Attribute unstated assumptions | 1 |
| 4 | Supposition and integration | 8. Supposition | 1 |
| | | 9. Integrate | 1 |
| 5 | Inference | 10. Deduce and judge deduction | 1 |
| | | 11. Make and judge value judgments | 2 |
| | | 12. Make material inference | 2 |
| Total | | | 17 |

In accordance with the method used, the research instrument used was a critical thinking skills test, which included a pretest and posttest, and was administered to both classes. The test was designed in a multiple-choice format, consisting of 17 questions. The test instrument was compiled based on indicators of achieving learning objectives in static fluid materials, adjusted to critical thinking indicators. Before use, this instrument underwent content validation by two lecturers who are experts in the field of physics education, considering the suitability of the static fluid material in relation to critical thinking indicators, and was deemed suitable for data collection purposes. The grid for students' critical thinking skills in static fluid material is presented in Table 2. NQ indicates the number of questions.

The data obtained is analyzed and further processed. The analysis was conducted through descriptive analysis to examine the categories of critical thinking skills, as well as inferential analysis to test the differences in critical thinking skills between the experimental and control classes.

## 3.5. Descriptive Analysis

Descriptive analysis involves summarizing and presenting data in its original form without drawing general conclusions (Sugiyono, 2019). Descriptive analysis is used to examine the critical thinking skills of students at SMA 15 Pekanbaru in classes that employ case-based learning and those that employ conventional learning.

Students' critical thinking levels were determined based on their total test scores. Responses were scored dichotomously (1 = correct, 0 = incorrect). After the total score is obtained, referring to

Ermayanti and Dwi in (Fazriah et al., 2024), the equations used to obtain critical thinking skills scores CS according to:

$$\text{CS} = \frac{S_t}{S_m} \times 100 \quad (1)$$

where $S_t$ is the total score obtained, and $S_m$ is the maximum score.

After the score is obtained, the mean score $(\overline{\text{X}})$ is calculated using Equation 2, as proposed by Aqib (2016).

$$\overline{\text{X}} = \frac{\sum \text{X}}{\sum \text{N}} \quad (2)$$

where $\sum \text{X}$ is total overall score, and $\sum \text{N}$ is total number of students.

The process of interpreting the results was carried out using a formula based on Supriyati et al. (2018) as follows:

$$\text{P} = \frac{\text{f}}{\text{N}} \times 100\% \quad (3)$$

where P is the percentage of achievement, f is the number of events on the percentage calculated, and N is the overall number of students.

### *3.6. Inferential Analysis*

To draw conclusions that can be applied to the population, an inferential test is conducted (Sugiyono, 2019). The pretest and posttest data on students' critical thinking skills are sample data that are analyzed inferentially using tests for normality, homogeneity, and hypothesis testing. The first step is to test the prerequisites, specifically normality and homogeneity tests. After the prerequisite test has been met, the next test can be carried out, namely the paired sample t-test and the independent sample t-test with a two-tailed test. The paired sample t-test technique is a statistical method for comparing the difference in means between two paired groups of data, based on the data collected before and after a specific treatment. Meanwhile, the independent sample t-test is used to test the difference in means between two unpaired groups (Nuryadi et al., 2017). The purpose of using this testing technique is to determine whether there is a significant difference in students' critical thinking skills between classes that employ the case-based learning model and those that use conventional learning methods with static or fluid material.

Furthermore, in order to see the magnitude of the increase in critical thinking skills that occurred after learning was given in both classes, the N-Gain test was then carried out using equations (Meltzer, 2002), which is as follows:

$$\text{N-Gain} = \frac{\text{S}_{post} - \text{S}_{pre}}{\text{SMI} - \text{S}_{pre}} \quad (4)$$

where $\text{S}_{post}$ is the posttest score, $\text{S}_{pre}$ is the pretest score, and SMI is the maximum ideal score. The level of N-Gain is determined as shown in the Table. 3 (Hake, 1998).

**Table 3.** *N-Gain criteria*

| N-Gain Score | Criteria |
|---|---|
| N-Gain $\geq 0{,}70$ | High |
| 0,30 < N-Gain < 0,70 | Medium |
| N-Gain $\leq 0{,}30$ | Low |

## 4. Result

### *4.1. Descriptive Analysis*

Descriptive analysis is a data analysis technique used to describe the critical thinking skills of students in classes XI C and XI D on the subject of static fluids at SMAN 15 Pekanbaru. After testing was carried out twice, namely before and after learning, the results for each category were interpreted in Table 4.

Tables 4 and 5 present the interpretation of students' critical thinking skills categories based on the results of the pretest and posttest. NS indicates the number of students. In the experimental class, the average pretest score was 25.70, which fell within the lower category, and then increased to an average posttest score of 72.74, which was in the good category. Meanwhile, in the control class, the average pretest score was 24.21, which was classified as less, then increased in the posttest with an average score of 60.18, which was classified as enough. The comparison of the pretest scores of the experimental class and the control class was not much different, indicating that the initial abilities of the two classes were relatively the same in the subject of static fluids.

**Table 4.** *Interpretation of students' scores in the experimental class*

| Intervals | Category | Pretest | | Posttest | |
|---|---|---|---|---|---|
| | | NS | (%) | N | (%) |
| $81 < x \leq 100$ | Very good | 0 | 0 | 12 | 34.29 |
| $61 < x \leq 81$ | Good | 0 | 0 | 16 | 45.71 |
| $41 < x \leq 61$ | Enough | 5 | 14.29 | 6 | 17.14 |
| $21 < x \leq 41$ | Less | 20 | 57.14 | 1 | 2.86 |
| $0 < x \leq 21$ | Very less | 10 | 28.57 | 0 | 0 |
| Average | | | 25.70 | | 72.74 |
| Category | | | Less | | Good |

**Table 5.** *Interpretation of students' scores in the control class*

| Intervals | Category | Pretest | | Posttest | |
|---|---|---|---|---|---|
| | | NS | (%) | NS | (%) |
| $81 < x \leq 100$ | Very good | 0 | 0 | 3 | 8.82 |
| $61 < x \leq 81$ | Good | 0 | 0 | 12 | 35.30 |
| $41 < x \leq 61$ | Enough | 3 | 8.82 | 17 | 50 |
| $21 < x \leq 41$ | Less | 18 | 52.94 | 2 | 5.88 |
| $0 < x \leq 21$ | Very less | 13 | 38.24 | 0 | 0 |
| Average | | | 24.21 | | 60.18 |
| Category | | | Less | | Enough |

Tables 4 and 5 also show that the average posttest scores of students in the experimental class, which used the case-based learning model, were higher than those in the control class, which used conventional learning. Analysis of student achievement in each aspect of critical thinking skills is presented in Table 6.

The analysis results show that the experimental class and the control class have differences in achievement in each aspect. In the pretest results of the experimental class, it can be seen that the highest percentage of achievement is in the aspect of advanced clarification, namely 37.14%, followed by the aspect of making a decision, namely 32.38%. In the control class's pretest results, the highest achievement percentage was in the aspect of advanced clarification, namely 32.35%, followed by the aspect of basic clarification, namely 30%. Meanwhile, the lowest achievement in both the experimental and control classes was in the aspect of supposition and integration.

**Table 6.** *Analysis of the achievement of students in each aspect*

| Aspects of Critical Thinking Skills | Class Achievement (%) | | | |
|---|---|---|---|---|
| | Experiment class | | Control class | |
| | Pretest | Posttest | Pretest | Posttest |
| Basic clarification | 20.57 | 75.42 | 30 | 57.05 |
| Based for a decision | 32.38 | 67.61 | 25.49 | 61.76 |
| Advance clarification | 37.14 | 82.85 | 32.35 | 73.52 |
| Supposition and integration | 15.71 | 48.57 | 7.35 | 36.76 |
| Inference | 26.28 | 78.85 | 21.17 | 66.47 |

The posttest results in the experimental class showed that the highest achievement percentage was in the aspect of advanced clarification, namely 82.85%, followed by the aspect of inference, namely 78.85%. In the control class post-test results, the highest achievement percentage was in the aspect of advanced clarification, namely 73.52%, followed by the aspect of inference, namely 66.47%. Meanwhile, the lowest achievement percentage in both the experimental and control classes was in the aspect of supposition and integration.

Based on Table 6, it can be concluded that the percentage of post-test achievement in the experimental class, which applied the CBL, was higher than in the control class, which applied conventional learning. This finding aligns with the study's results, which indicate that the application of the case-based learning model can enhance students' critical thinking skills (Arsana et al, 2024). In their study, the class that implemented the CBL showed a higher category of critical thinking skills compared to the class that did not implement it.

### *4.2. Inferential Analysis*

After the data are analysed descriptively, the next step is to analyse them inferentially. The first step is to examine the prerequisites, whether the data is normal and homogeneous. Once these criteria are met, the next process is the hypothesis testing stage. The analysis used is a paired sample t-test, which determines whether there is a statistically significant difference between the pre- and post-learning conditions. The paired-samples t-test results indicate statistically significant differences between the pretest and posttest scores in both groups. For the experimental classes, the significance value (2-tailed) is 0.000, indicating a statistically significant change from pretest to posttest. Likewise, the control class also yields a significance value (2-tailed) of 0.000, indicating a significant pretest–posttest difference.

Upon reviewing the posttest results more closely, an independent sample t-test is conducted. From this test, it is evident that there is a difference in post-test results between the group that participated in learning with the CBL and the group that participated in conventional learning. The test results are interpreted in Table 7. Sig2 indicates the Significance 2-tailed, and MD is Mean Difference.

**Table 7.** *Independent t-test result*

| | F | Sig. | t | df | Sig2 | MD |
|---|---|---|---|---|---|---|
| Equal variances assumed | 0,029 | 0,865 | 3,948 | 67 | 0,000 | 12,56104 |
| Equal variances not assumed | | | 3,948 | 66,953 | 0,000 | 12,56104 |

The significance p-value obtained in Table 7 is 0.000 <0.05. Based on the findings of this test, it is evident that there is a distinction between the group that participates in learning with the case-based learning model and the group that learns using conventional learning.

Each class experienced an improvement in critical thinking skills. However, upon observing the difference in improvement between the two classes, it is necessary to conduct an N-Gain test. The results obtained from this test are presented in the following table.

**Table 8.** *N-gain t-test result*

| | N | Minimum | Maximum | Mean | Sig. |
|---|---|---|---|---|---|
| Experimental Classes | 35 | 0.15 | 0.92 | 0.6425 | 0.00 |
| Control Class | 34 | 0.18 | 0.82 | 0.4785 | 0 |

Table 8 shows that the mean N-Gain score for the experimental class is 0.6425, which falls into the medium category. N-Gain differentiation testing between the two groups showed a significant p-value of 0.000 < 0.05, indicating that the acceleration of critical thinking skills between the two groups was different. The increase was superior in the group that applied the case-based learning method compared to the group that used the conventional learning method.

From the data analysis, it was found that the average percentage of the experimental class learning with the case-based learning model differed for each aspect, as shown in Figure 2.

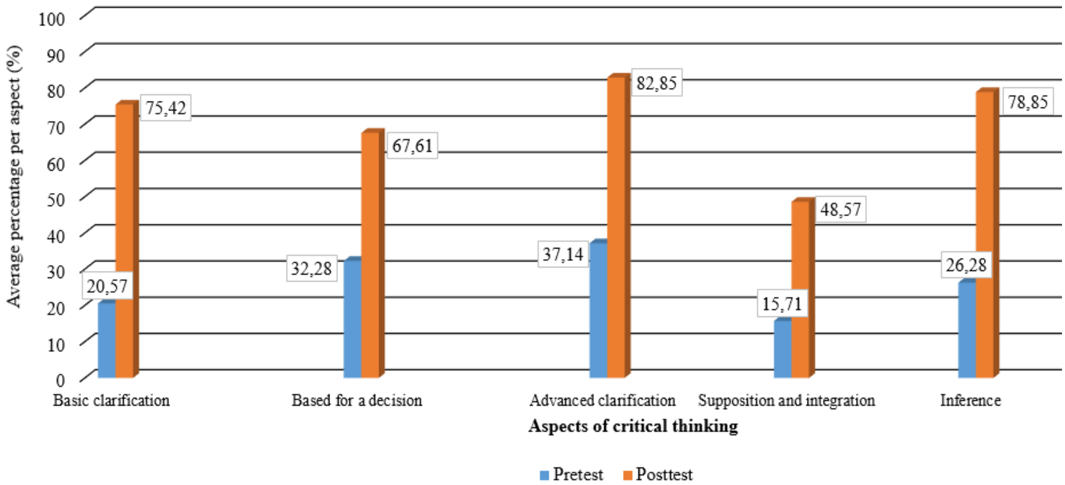


**Figure 2.** *Average percentages of the experimental class for each aspect*

From the image above, it is known that each aspect has experienced a different increase. To examine more deeply the percentages in each aspect, which are as follows:

1. Basic clarification. In this aspect, the posttest result obtained a percentage of 75.42%. This aspect can be strengthened when students are given examples of real phenomena, allowing them to compare the events that occurred and formulate basic explanations (Ridho et al., 2020).
2. Based on the decision. The result of the posttest in this aspect was 67.61%. Basic skills contribute significantly to the development of critical thinking skills, as students are more interested in exploring and identifying new things they acquire from various sources with the help of the cases presented (Wayudi et al., 2020).
3. Advanced clarification. The result of the posttest on critical thinking skills in this aspect was 82.85%. The increase is mediated by the complex nature of the cases in CBL, which requires students to gather information and analyse data in depth (Fatimah & Nurita, 2023).
4. Supposition and integration. The percentage of achievement in this aspect is still in the sufficient category, which is 48.57%. It also explains that this condition arises because students have not been able to combine all the information obtained and have not been skilled in formulating the most effective solution strategy for the given case.
5. Inference. The result of the posttest *on* critical thinking skills in this aspect was 78.85%. This aspect shows an improvement because it relates to individual skills in examining facts, formulating and defending ideas, making comparisons, and finally drawing conclusions that are used to solve problems (Fatimah & Nurita, 2023).

Based on the analysis results presented earlier, the average posttest score of the experimental class was 72.74, which was categorized as good. In contrast, the control class achieved an average posttest score of 60.18, which falls into the sufficient category. The difference between the two classes was 12.56, with the experimental class, which was taught using the CBL model, achieving higher performance. The description suggests that this CBL can enhance students' critical thinking skills, particularly in this study, which focuses on static fluid materials.

The results of this study align with the findings of previous relevant studies. One of them is a study conducted by Kusumawati et al. (2019) which examined the effect of integrating the SE cycle learning model with CBL on students' critical thinking tendencies. The study revealed that the experimental class achieved an average score of 94.43%, while the control class scored 88.89%, resulting in a difference of 5.54 percentage points. Similar research was also conducted by Nisa et al. (2024), researchers who implemented the 5E instructional model, accompanied by the case method of virus material, to examine the critical thinking skills and learning outcomes of 10th-grade high school students. The results showed that the experimental class achieved a critical thinking skill score of 84.38%, while the control class reached only 55.38%, resulting in a 29.10% difference.

Data analysis was also conducted inferentially through a series of statistical tests. Prerequisite tests were performed first, followed by hypothesis testing using the t-test. The test results showed a significance value (Sig. 2-tailed) of 0.000 in both class groups. Based on the decision-making criteria, if the significance value is less than 0.05, the alternative hypothesis is rejected, and the null hypothesis is accepted. Therefore, it can be concluded that there is a difference in students' critical thinking skills between classes that employ the case-based learning model and those that use conventional learning methods with static or fluid material.

Furthermore, the N-Gain analysis of pretest and posttest scores showed that the experimental class achieved an N-Gain value of 0.6425, while the control class obtained a value of 0.4785. The N-Gain difference test between the two groups yielded a significance value of 0.000 ($< 0.05$), indicating a statistically significant difference in the improvement of critical thinking skills between the experimental and control classes. These findings demonstrate that the increase in critical thinking skills among students taught using the Case-Based Learning model was greater than that of students who received conventional instruction.

## 5. Discussion

### *5.1 Interpretation Of Finding*

Each stage in the case-based learning is designed to train and develop students' critical thinking skills. Starting from the established cases, students are encouraged to provide simple explanations of the problems they face. Furthermore, through the stages of analysing cases and collecting information, data, and literature, students are trained to identify problems, process information, and consider evidence logically. The problem-solving process through group discussions helps students integrate various information and formulate rational solutions. The presentation and verification stage by the teacher further strengthens students' understanding, enabling case-based learning to relate the concept of static fluids to real-world problems while optimizing the development of critical thinking skills.

This improvement is related to the characteristics of CBL, which places the student at the center of the learning process. Furthermore, this model encourages students to be actively involved in class through both group discussions and the resolution of real-world cases. This process serves as an essential source for knowledge construction. Engagement in analyzing cases, identifying problems, and formulating alternative solutions fosters the development of critical thinking skills (Andini et al., 2023).

Both CBL and conventional learning share the same objective: delivering curriculum-aligned material and helping students understand fundamental physics concepts, including static fluids. Both involve interactions between teachers and students during the learning process and utilize assessments to measure learning outcomes. However, conventional learning tends to be teacher-centered, with the teacher acting as the dominant and primary source of information. Consequently, students tend to be passive, receiving information unidirectionally without active involvement in building their understanding (Silaban & Wuriyani, 2024). This distinction demonstrates that the implementation of CBL successfully creates a more meaningful learning experience, encouraging students to be more active in interpreting, analyzing, evaluating, and elaborating on information rationally. These conditions represent a key factor why the experimental class showed a greater increase in critical thinking skills compared to the control class (Wafika Rahma Diyanti, 2024).

The findings indicate that the advanced clarification aspect demonstrates the greatest improvement among the indicators of critical thinking skills. This outcome can be attributed to the nature of the cases presented in CBL, which require students to explain phenomena in greater depth by connecting theoretical concepts with empirical evidence. During the analysis and problem-solving stages, students are guided to elaborate their reasoning, justify their arguments using relevant physical principles, and relate experimental data to conceptual understanding. This repeated practice of explaining concepts in a structured and evidence-based manner strengthens students' ability to construct advanced explanations. Consequently, CBL effectively facilitates deeper conceptual processing, leading to a more pronounced improvement in the advanced clarification aspect of students' critical thinking skills.

### *5.2 Implication*

This study has several strengths that contribute significantly to the practice of physics education. One of the main strengths lies in the implementation of the CBL, which does not rely on advanced technology. This characteristic makes the learning model relevant for schools with limited facilities as well as for regions experiencing uneven development of educational technology.

Additionally, the cases used in the learning process are closely related to static fluid phenomena that students encounter in their daily lives. This approach enables students to connect physics concepts with real-life situations, making learning more contextual and aligned with students' cultural backgrounds and learning environments. The alignment between instructional content and students' real-life contexts contributes to the enhancement of students' critical thinking skills and deepens their conceptual understanding.

Furthermore, the findings of this study have broader implications in a global context. The results indicate that CBL can serve as an effective and inclusive instructional strategy for developing critical thinking skills without requiring complex technological infrastructure. Therefore, this learning model has the potential to be widely implemented across various educational systems, contributing to the equitable and sustainable improvement of physics education quality.

### *5.3 Limitation*

This research was conducted in a school context with a limited sample size, so the results obtained reflect the characteristics of the students and the learning environment at the research location. In addition, the use of a quasi-experimental design placed the study in a natural learning condition, allowing the analysis to focus on measuring critical thinking skills through test instruments. Further research is suggested to involve a broader range of samples and integrate various data collection techniques to enhance the understanding of case-based learning implementation.

## 6. Conclusion

The implementation of Case-Based Learning (CBL) in static fluid materials is more effective than conventional learning in enhancing students' critical thinking skills. The difference in achievement between the experimental and control groups confirms that CBL strengthens critical thinking processes by engaging students in analyzing contextual problems, engaging in discussions, gathering and evaluating information, formulating solutions, and presenting and verifying conclusions argumentatively.

Consequently, CBL is recommended as an alternative physics learning model in schools, particularly when instruction is aimed at strengthening reasoning and evidence-based decision-making. However, implementing CBL requires more meticulous time management and instructional planning to ensure that collaborative activities and case investigations proceed effectively. Further research is suggested to test its application in more diverse contexts and to enrich the evidence through broader data collection approaches.

## Authors' Contribution

**Nesty Mungianty Simanullang**: Conceptualization, Methodology, Data curation, Formal analysis, Writing – original draft. **Muhammad Nasir**: Conceptualization, Methodology, Supervision, Writing – review & editing. **Fakhruddin Z.**: Conceptualization, Methodology, Supervision, Writing – review & editing. All authors have reviewed and approved the final manuscript and agreed to the order of authorship.

## Ethical statement

This study was conducted in regular classroom teaching settings and was classified as minimal-risk educational research under the institutional guidelines of Riau University. Permission to conduct the study and to collect data in the participating classes was obtained through an official research permission letter from the relevant institutional authorities. Participation in the study was entirely voluntary. All participants were informed about the purpose of the research and the procedures involved. Informed consent was obtained from all participants. No sensitive personal data was collected. All responses were anonymized and used solely for research purposes.

## Declaration of AI use

The authors used artificial intelligence–assisted tools solely for language editing purposes, including improving clarity, readability, and overall writing quality. The use of these tools was limited to linguistic support and did not involve data analysis, interpretation of results, or generation of scientific content. All AI-assisted outputs were carefully reviewed and revised by the authors, who remain fully responsible for the accuracy, originality, and integrity of the final manuscript.

## Conflict of Interest

The authors declare that there is no conflict of interest, either financial or non-financial, that could be perceived as influencing the work reported in this manuscript. All authors have reviewed and approved this statement.

## Supplementary Materials and Data Availability

No public repository is currently available for the dataset of this study. However, the research instruments and key data summaries used in this study can be obtained from the corresponding author upon reasonable request. Any data shared will be anonymized and provided in accordance with the ethical approval and institutional regulations.

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