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The Effect of the CTL Model on Students' Critical Thinking Skills in Static Fluids

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Abstract. The low level of students' critical thinking skills in physics subjects especially fluids static is a problem that includes understanding concepts and applying knowledge in real-world contexts. This study aims to examine the effect of the Contextual Teaching and Learning (CTL) model on students' critical thinking skills in the topic of static fluids. A quasi-experimental method with a non-equivalent control group design was employed involving 66 eleventh-grade students at SMA Negeri 98 Jakarta, divided into an experimental group receiving CTL instruction and a control group taught using conventional methods. Critical thinking data were collected through a test based on Tiruneh's indicators and analyzed using the Independent Sample T-Test and N-Gain calculation. The results indicate a significance value of 0.022 (< 0.05) and an N-Gain of 0.60 for the experimental group, higher than the control group's 0.43. These findings demonstrate that CTL significantly enhances students' critical thinking skills. The implications suggest that CTL is suitable for physics learning, especially for abstract topics such as static fluids, to strengthen cognitive skills and promote more meaningful learning.

Keywords: contextual teaching and learning, critical thinking, static fluids

1. Introduction

In the twenty-first century, critical thinking has become one of the essential skills that students must possess to navigate various global challenges [1]. Critical thinking refers to the ability to arrive at conclusions accurately, systematically, and with sound reasoning, allowing it to serve as an alternative framework for making judgments [2]. In addition, critical thinking is not only concerned with analyzing and evaluating information objectively, but also with the capacity to solve complex problems and make well-informed decisions. It is widely regarded as a foundational skill that supports the development of other competencies needed in the workplace and in everyday life [3].

Field observations indicate that students' critical thinking skills in physics learning remain at a moderate to low level. According to the four-year cycle analysis of the Trends in International Mathematics and Science Study (TIMSS), Indonesia ranks sixth from the bottom [4]. In 2012, Indonesia also took part in the Programme for International Student Assessment (PISA) and placed 64th out of 65 participating countries. PISA tasks are grouped into six levels; levels 1 to 3 are categorized as lower-order thinking skills (LOTS), while levels 4 to 6 represent higher-order thinking skills (HOTS). The results show that Indonesian students generally perform only at levels 1 to 3, whereas many other countries have students who achieve levels 4, 5, or even 6 [5]. Findings from international assessments such as TIMSS and PISA provide important insights into the quality of education in Indonesia, revealing that students tend to master items requiring low-level cognitive processes, such as routine problems, simple computations, and factual knowledge in everyday contexts [6]. Furthermore, [7] reports that "higher-order thinking skills among Indonesian students remain low," largely because classroom instruction continues to emphasize memorization rather than analytical thinking, creativity, or problem-solving.

If students' critical thinking skills continue to remain low in physics learning, particularly in the topic of static fluids, the consequences can be quite detrimental. Students may only grasp basic concepts without being able to evaluate, analyze, or critique ideas in a deeper and more complex manner. While some students are capable of giving simple explanations, many still struggle to draw conclusions or articulate tactical reasoning in a critical way [8]. An appropriate and effective instructional model has been shown to enhance students' critical thinking skills in static fluid concepts, with improvements reaching up to 70.52%. This suggests that without active and well-designed learning interventions, the development of critical thinking skills is likely to remain limited [9].

To address this issue, the present study employs the Contextual Teaching and Learning (CTL) model as an instructional approach that is considered capable of enhancing students' critical thinking skills. The implementation of CTL has been shown to strengthen critical thinking by helping students connect academic content with real-life situations [10]. CTL is recognized as one of the learning models that can foster the development of critical thinking skills. Within the CTL framework, students are expected to take an active role in exploring the learning material and relating it to authentic, everyday contexts in which the concepts can be applied [11].

Based on this background, the present study aims to quantitatively examine the effect of implementing the CTL model on improving students' critical thinking skills in the topic of static fluids. This research is expected to demonstrate a significant difference in the critical-thinking gains between students who learn through the CTL approach and those who receive conventional instruction, thereby providing concrete evidence that supports efforts to enhance the quality of physics education in Indonesia.

2. Method

This study adopts a quantitative approach with a quasi-experimental design involving two non-randomized groups: an experimental group and a control group. Both groups were first administered a pre-test to assess their initial critical thinking abilities. The control group received conventional instruction, while the experimental group engaged in learning activities based on the Contextual Teaching and Learning (CTL) approach. After the intervention, a post-test was administered to both groups to evaluate the improvement in their critical thinking skills as an outcome of the instructional model applied.

The implementation of CTL in the static fluids topic was carried out by linking the concepts of hydrostatic pressure, buoyant force, surface tension, and viscosity to real-life contextual situations. The learning process included observing phenomena, conducting simple experiments, participating in group discussions, and engaging with conceptual models provided by the teacher. Students were guided to carry out inquiry-based activities, respond to guiding questions, and reflect on the outcomes of their learning experiences. Assessment was conducted through context-based worksheets as a form of authentic evaluation.

The population in this study consisted of 11th-grade science-track students at SMA Negeri 98 Jakarta during the first semester of the 2025/2026 academic year. From this population, the research sample was selected using purposive sampling, in which participants were chosen based on specific criteria to serve as relevant data sources [12]. Based on these criteria, the sample comprised 66 students from two classes 33 students in the experimental group and 33 students in the control group.

The research procedure was carried out in three stages: the preliminary stage, the implementation stage, and the final stage. The preliminary stage involved conducting a preliminary study, formulating the research problem, developing test instruments, preparing the lesson plans (RPP) and student worksheets (LKPD), as well as validating the instruments and analyzing the validation results. The implementation stage included administering the pre-test, conducting the learning activities, and administering the post-test. The final stage consisted of analyzing the research data, testing the hypotheses, and drawing conclusions.

The instruments used in this study were developed based on critical-thinking indicators. These indicators consisted of five components, represented through fifteen essay questions, which included:

reasoning, hypothesis testing, argument analysis, analysis of probability and uncertainty, and problem solving and decision making [13]. The instrument blueprint is presented in Table 1.

Table 1. Instrument blueprint.

No	Indicator	Sub Indicator	Item Numbers
1.	Reasoning	Evaluating the validity of data Identifying measurement errors Interpreting experimental results Detecting ambiguity and misuse of definitions	1, 5, 9, 12
2.	Hypothesis testing	Interpreting relationships between variables Gathering additional information to draw conclusions Identifying the causes of an event Drawing valid conclusions from data presented in tables or graphs Examining whether the sample size is adequate and whether bias may occur when generalizing results	2, 6, 10, 13
3.	Argument analysis	Identifying the main idea of an argument Critiquing the validity of generalizations in an experiment Assessing the credibility of an information source Deriving accurate statements from a given set of data Identifying missing information within an argument	3, 7, 14
4.	Likelihood and uncertainty analysis	Predicting the likelihood of an event Identifying underlying assumptions Using probabilistic judgment to make decisions Calculating expected values in situations with known probabilities Recognizing the need for additional information when making decisions	8, 15
5.	Problem solving and decision making	Identifying alternative solutions to a problem Examining the relevance of procedures used in solving scientific problems Recognizing the characteristics of a problem and planning an appropriate solution Evaluating solutions and making decisions based on evidence	4, 11

The instrument was evaluated by three expert judges. The content validation was examined across three aspects: material, language, and construct. Content validity was calculated using the Content Validity Ratio (CVR), followed by the computation of the Content Validity Index (CVI) based on the CVR values [14]. For the language aspect, the CVI score obtained was 0.88, indicating a very high level of validity. The material aspect achieved a CVI score of 0.90, which also falls within the "highly valid" category. Meanwhile, the construct aspect produced a CVI score of 0.94, likewise categorized as highly valid. Subsequently, validity testing was carried out using the Pearson Product-Moment method, with the results presented in Table 2.

Table 2. Validity test results.

No	Correlation	R-table	Decision
1.	0.873	0.361	Valid
2.	0.858	0.361	Valid
3.	0.859	0.361	Valid
4.	0.865	0.361	Valid
5.	0.875	0.361	Valid
6.	0.882	0.361	Valid
7.	0.884	0.361	Valid
8.	0.863	0.361	Valid
9.	0.922	0.361	Valid
10.	0.862	0.361	Valid
11.	0.878	0.361	Valid
12.	0.882	0.361	Valid

No	Correlation	R-table	Decision
13.	0.917	0.361	Valid
14.	0.859	0.361	Valid
15.	0.807	0.361	Valid

Based on the data obtained, all 15 test items that were examined were found to be valid. These validated items were then further analyzed to determine their reliability, difficulty level, and discrimination power. Reliability testing was carried out using the Cronbach's Alpha method, yielding a coefficient of 0.977, which falls into the "very high" reliability category. This result indicates that the instrument is reliable and suitable for use in the study [15]. Subsequent analyses of item difficulty and discrimination indices were also conducted, with the results presented in Table 3.

Table 3. Difficulty level and discrimination power results.

No	Difficulty Level		Discrimination Index	
	Difficulty Level	Description	Discrimination Index	Description
1.	0.70	Moderate	0.42	Excellent
2.	0.60	Moderate	0.31	Good
3.	0.63	Moderate	0.33	Good
4.	0.57	Moderate	0.33	Good
5.	0.76	Easy	0.36	Good
6.	0.69	Moderate	0.31	Good
7.	0.67	Moderate	0.31	Good
8.	0.71	Easy	0.36	Good
9.	0.50	Moderate	0.33	Good
10.	0.79	Easy	0.33	Good
11.	0.68	Moderate	0.33	Good
12.	0.78	Easy	0.31	Good
13.	0.59	Moderate	0,47	Excellent
14.	0.29	Difficult	0.44	Excellent
15.	0.58	Moderate	0.36	Good

The data analysis included descriptive statistical tests used to describe the characteristics of the collected data [16]. Normality and homogeneity tests were then conducted to determine the appropriate statistical procedures. The Shapiro-Wilk test was employed to assess normality, as it is generally recommended for sample sizes below 50 [17]. Homogeneity was examined using Levene's test. When all prerequisite assumptions were met, parametric statistical tests were subsequently applied.

3. Result and Discussion

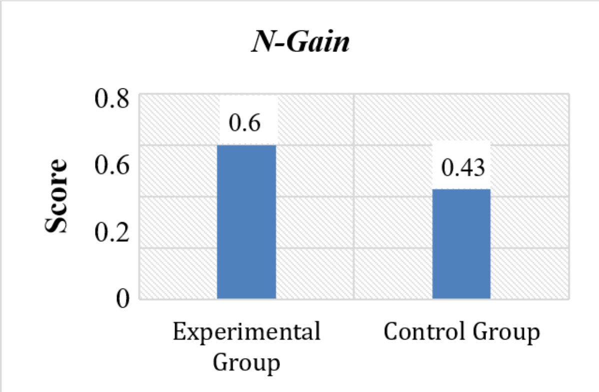
This study examines the effect of the Contextual Teaching and Learning (CTL) model on students' critical thinking skills in the topic of static fluids. The pre-test and post-test scores are presented in Table 4.

Table 4. Pre-test and post-test results of critical thinking.

Data Category	Experimental Group		Control Group	
	Pre-test	Post-test	Pre-test	Post-test
Ideal Score	100	100	100	100
Maximum Score	87	98	87	98
Minimum Score	31	60	47	51
Mean Score	60.12	83.73	62.55	78.12
Median Score	60	84	62	78
Standard Deviation	11.675	9.850	9.750	9.539

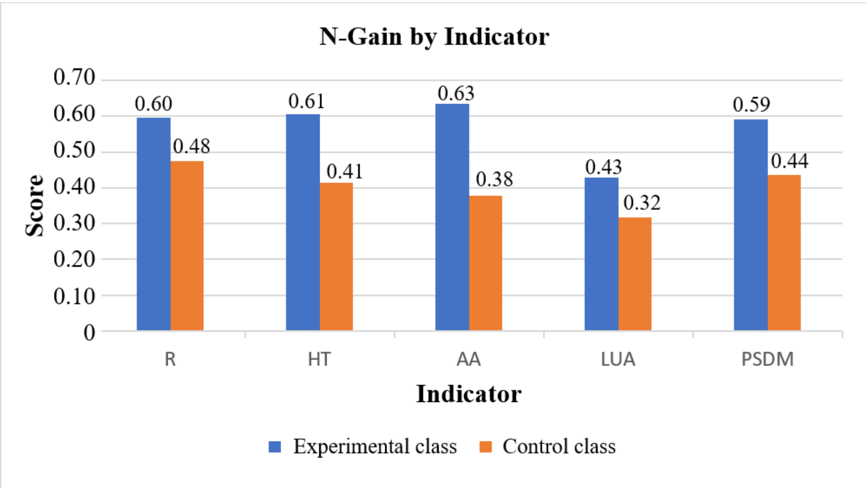
The results presented in Table 4 show the mean pre-test and post-test scores for both groups. The experimental group obtained an average pre-test score of 60.12, while the control group achieved 62.55; thus, the mean scores of both groups were relatively comparable. This indicates that the two groups had equivalent initial abilities before the intervention was administered. A similar pattern is observed in the median scores. The score ranges also reflect comparable variability between the experimental and control groups. However, following the intervention, the experimental group demonstrated a notable improvement, achieving a post-test average of 83.73, whereas the control group reached only 78.12. These results suggest that the Contextual Teaching and Learning (CTL) model effectively enhanced the critical thinking skills of students in the experimental class. The N-gain scores for critical thinking in both groups are presented in Figure 1.

Figure 1. N-Gain result.



Based on Figure 1, the differences in the average N-Gain scores between the experimental group and the control group are presented. The experimental group achieved an N-Gain score of 0.60, indicating a moderate improvement in critical thinking skills on the topic of static fluids. Meanwhile, the control group showed an N-Gain score of 0.43, also indicating a moderate improvement in critical thinking skills on the same topic. It is evident that the increase in the N-Gain score of the experimental class remains higher. A comparison of the N-Gain scores for each critical thinking indicator between the experimental and control groups can be observed in Figure 2.

Figure 2. N-Gain Results of Critical Thinking Skills



Based on Figure 2, it can be seen that the N-Gain scores of the experimental group are consistently higher than those of the control group across all indicators of critical thinking skills. The highest N-Gain in the experimental group was observed in the Argument Analysis indicator, with a score of 0.63 (moderate). The lowest N-Gain in the experimental group was found in the Likelihood and Uncertainty Analysis indicator, with a score of 0.43 (moderate). Meanwhile, the N-Gain scores of the control group were relatively lower than those of the experimental group for each indicator. These results indicate that the improvement in students' critical thinking skills in the experimental class was higher (significant) compared to the control class. Next, assumption tests were conducted to determine the appropriate inferential tests. The results of the normality test using the Shapiro-Wilk test are presented in Table 5, and the homogeneity test using Levene's Statistic is shown in Table 6.

Table 5. Normality Test Results

Shapiro-Wilk	Pre-test		Post-test	
	Experimental Group	Control Group	Experimental Group	Control Group
Significance	0.56	0.595	0.128	0.385
Decision	Normal Data	Normal Data	Normal Data	Normal Data

Table 6. Homogeneity Test Results

Type	sig	Result
Based on mean	0.568	Homogeneous Data
Based on median	0.580	Homogeneous Data

Table 6 presents the results of the normality test using the Shapiro-Wilk test, indicating that the pre-test and post-test data are normally distributed. Furthermore, Table 7 shows that both groups have homogeneous variances. The homogeneity test was conducted using two statistical approaches: "Based on Mean" and "Based on Median," both of which indicated homogeneous data. Both significance values were greater than the critical value of $\alpha = 0.05$. Since the assumptions have been met, parametric tests can be performed. The first parametric test conducted was the paired sample t-test, as shown in Table 7.

Table 7. Paired Sample t-Test Results

Comparison	Sig. (2-tailed)
Pre-test and pos-test (Experimental Group)	0.003
Pre-test and post-test (Control Group)	0.000

The results of the experimental group, which used the CTL model, showed a significance value of 0.003. This value is below the significance threshold of 0.05, indicating a significant difference between the pre-test and post-test scores. A similar result was observed in the control group, where the significance value was 0.000, suggesting that both groups experienced an improvement in performance from pre-test to post-test. The next step was to conduct an independent sample t-test to examine the differences in scores between the two groups. The results are presented in Table 8.

Table 8. Independent Sample t-Test Results

Comparison	Sig. (2-tailed)
Pre-test	0.363
Post-test	0.022

Table 8 shows that the pre-test results yielded a significance value of 0.363, which is well above 0.05. This indicates that there was no significant difference in the initial abilities of the two groups. In contrast, the post-test results showed a significance value of 0.022, which is below 0.05, indicating that the CTL model had a significant effect on students' critical thinking skills in the topic of static fluids.

The findings of this study demonstrate that the implementation of the Contextual Teaching and Learning (CTL) model has a significant impact on improving students' critical thinking skills in static fluids. The higher average post-test score of the experimental group compared to the control group indicates that the CTL model positively influences the enhancement of students' critical thinking abilities. Furthermore, in accordance with previous research [10], it has been stated that the CTL model is one of the most effective instructional approaches for improving students' critical thinking skills.

The results of the study indicate a significant improvement in critical thinking skills in the group taught using the CTL model, with an average N-Gain score of 0.60 (moderate category) compared to the control group, which had an average N-Gain of 0.43 (moderate category). This demonstrates the positive impact of implementing the CTL model. The greatest improvement occurred across the five indicators of critical thinking, with the highest gains in the argument analysis indicator, followed by hypothesis testing, reasoning, problem solving and decision making, and likelihood and uncertainty analysis. These findings are consistent with the results reported by [18] and [19], which show that the Contextual Teaching and Learning (CTL) model positively influences students' critical thinking skills.

The increase in the argument analysis indicator in this study is logical, as students demonstrated significant improvement in constructing arguments based on theoretical concepts such as hydrostatic pressure, Archimedes' principle, surface tension, and viscosity, supported by empirical evidence through direct experimentation during practical activities. This finding aligns with the systematic review by [20], which showed that students' argumentation skills in physics are influenced by the teaching model, instructional approach, teacher guidance, and learning environment. By implementing the CTL model, which connects physics theory with real-world phenomena while providing opportunities for students to discuss, evaluate arguments, and reflect on the learning process, students' ability to analyze arguments was enhanced. In contrast, the likelihood and uncertainty analysis indicator showed the lowest improvement, as students were less capable of predicting experimental outcomes and evaluating data scientifically. This finding is consistent with the research by [21], which indicates that students' understanding of sources of uncertainty in physics experiments strongly depends on the experimental context and their theoretical knowledge.

In contrast to the experimental group, the control group obtained significantly lower N-Gain scores across all indicators of critical thinking skills. These results suggest that without specific instructional interventions, the critical thinking abilities of students in the control group tended to show little meaningful development in the topic of static fluids. This condition indicates that conventional teaching methods are not yet able to optimally stimulate and train critical thinking skills, highlighting the need for the implementation of a more effective Contextual Teaching and Learning (CTL) model [22].

The findings of this study reinforce the theoretical framework that the abstract nature of static fluids is more effectively understood through the Contextual Teaching and Learning (CTL) model. Students demonstrated effective learning of static fluids when the instructional material was contextually based, aligning with the findings of [23]. This study contributes by providing evidence of the specific impact of the CTL model on students' critical thinking skills in the topic of static fluids.

4. Conclusion

The Contextual Teaching and Learning (CTL) model enhances critical thinking skills in the topic of static fluids, as evidenced by the higher average post-test scores of the experimental group compared to the control group. The indicator that showed the greatest improvement was argument analysis, while most other indicators, such as reasoning, hypothesis testing, likelihood and uncertainty analysis, and problem solving and decision making, also demonstrated notable gains.

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