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The Effect of Critical Thinking Skill Categories on Students' Cognitive Learning Outcomes in Dynamic Fluids Topic

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Abstract. The objective of this study is to determine the difference in the influence of critical thinking skill categories on students' cognitive learning outcomes in dynamic fluid topic. Education is a process aimed at helping students develop their potential, encompassing intellectual, moral, and life skills development. In senior high school (SHS), physics is a compulsory subject that many students find challenging. Research indicates that numerous students struggle to comprehend physics material, particularly dynamic fluids. The low learning outcomes are also influenced by the still-limited critical thinking skills among students in Indonesia. The use of a STEM approach combined with a Problem-Based Learning (PBL) model can enhance critical thinking skills and learning outcomes. This study employs a quasi-experimental design with a quantitative approach, utilizing a 2x2 factorial design. Two groups were tested: an experimental group taught using a STEM-PBL e-module and a control group using a conventional physics textbook. The population consisted of all 11th-grade science students at Senior High School 3 Surakarta. Two classes were selected as samples using cluster random sampling: XI-F1 (experimental) and XI-F3 (control). Data collection techniques included documentation, tests, and observation. Hypothesis testing was conducted using two-way ANOVA after meeting classical assumption tests, followed by Scheffe's post-hoc comparison. The hypothesis test results indicate a significant difference in the influence of high and low critical thinking skills on students' cognitive learning outcomes in dynamic fluid material).

Keywords: Critical Thinking skills, Cognitive Learning, Dynamic Fluids.

INTRODUCTION

Education is a systematic and structured effort to create a learning environment and process that enables students to actively develop their potential (Mahdiya et al., 2021). The goals of education encompass intellectual development, spiritual growth, moral character, self-discipline, and life skills necessary for active participation in society, nation-building, and statehood (Zhang et al., 2022). Physics, as a core subject in the Natural Sciences track at the senior high school (SHS) level, is often perceived as challenging due to its complex mathematical concepts and in-depth understanding of natural phenomena (Harefa, 2019). Specifically, in the topic of dynamic fluids, students are required not only to master mathematical equations but also to deeply comprehend fluid flow principles, pressure, flow rate, and Bernoulli's law (Anggraeni, 2019). However, research indicates a high

prevalence of misconceptions in this topic, reaching 62.38% (Ramadhani et al., 2022). These misunderstandings frequently occur in interpreting the relationship between cross-sectional area, flow velocity, and fluid pressure (Asnita et al., 2023). Consequently, students' cognitive learning outcomes in this topic tend to be low (Budianti et al., 2023).

The low cognitive learning outcomes correlate with students' critical thinking skills (Syamsinar et al., 2023). Critical thinking serves as a fundamental foundation in learning, particularly in science subjects like physics, as it helps students analyze problems, evaluate information, and make logical decisions (Hamdani et al., 2019). However, PISA 2019 data revealed that Indonesian students' critical thinking skills remain low, ranking 74th out of 79 countries (Kurniawati, 2022). This is also reflected in physics education, where many students struggle to grasp abstract concepts, including dynamic fluids (Vuztasari & Diyana, 2024). Studies conducted in several high schools, such as SMA Negeri 3 Pontianak and SMA Negeri 5 Medan, indicate that students' critical thinking skills in physics remain subpar, particularly in areas such as analysis, reasoning, and drawing conclusions (Nurjanah et al., 2022; Siregar et al., 2020). Contributing factors include conventional teaching methods, limited use of interactive media, and inadequate laboratory facilities (Maiyena & Imamora, 2020; Nadiya et al., 2022).

One proposed solution is the development of STEM-based e-modules (Science, Technology, Engineering, and Mathematics) using a Problem-Based Learning (PBL) approach. STEM-PBL learning has proven effective in enhancing students' critical thinking skills and learning outcomes (Erdoğan, 2019; Morrison et al., 2020). These e-modules are designed to facilitate independent learning by presenting material in the form of text, images, videos, and interactive exercises (Dewi & Lestari, 2020). Previous studies by Safitri (2022) and Yudha et al. (2024) demonstrate that PBL- and STEM-based e-modules can improve conceptual understanding and critical thinking skills. However, there remains a scarcity of research examining the effect of critical thinking skill categories (high vs. low) on cognitive learning outcomes, particularly in dynamic fluids.

Addressing this research gap, this study aims to analyze the influence of critical thinking skill categories (high and low) on students' cognitive learning outcomes in dynamic fluids. By understanding the relationship between critical thinking levels and cognitive achievement, educators can design more targeted learning strategies, such as enrichment for high-ability students or scaffolding for those with lower proficiency. The findings of this study are expected to contribute to the development of more adaptive and effective physics instruction, particularly in enhancing students' conceptual understanding and critical thinking skills.

METHOD

This study adopts a quasi-experimental quantitative approach with a 2x2 factorial design involving two distinct groups: an experimental group utilizing the STEM-PBL e-module and a control group employing the standard Merdeka Curriculum physics textbook. Prior to data collection, both groups underwent equivalence testing using the Liliefors test for normality, Bartlett's test for homogeneity, and a two-tailed T-test to ensure comparable baseline conditions. The research was conducted at SMAN 3 Surakarta, located at Jl. Prof. Yohanes No.58, Purwodiningratan, Jebres, Surakarta, Central Java, spanning both odd (September-December 2024) and even (January-May 2025) semesters of the 2024/2025 academic year. The implementation was carried out in three stages: preparation, execution, and completion. The population in this study consisted of all 11th-grade science students at the school. Using cluster random sampling, two classes were randomly selected as the research sample: class XI-F1 as the experimental group and class XI-F3 as the control group, with each class comprising 36 students, resulting in a total sample of 72 students.

The independent variables in this study were STEM-PBL e-module-assisted learning and problem-based learning using the Merdeka Curriculum textbook, both focused on dynamic fluids material. The dependent variable was students' cognitive learning outcomes, while critical thinking skills were treated as a moderator variable. Data collection techniques included documentation, testing,

and observation. The instruments used in this study were: (1) a 30-item multiple-choice test to measure cognitive learning outcomes, validated by expert judgment and tested for reliability; (2) a critical thinking skills test consisting of 8 essay questions developed based on Ennis's indicators of critical thinking, scored using an analytical rubric; (3) observation sheets to monitor the implementation of learning activities; and (4) documentation to collect supporting data such as students' prior academic records. Before hypothesis testing, assumption tests were conducted using the Liliefors test for normality at a 5% significance level and Bartlett's test for homogeneity. Inferential analysis was carried out using two-way ANOVA, followed by Scheffé's post-hoc test to identify specific group differences.

RESULT AND DISCUSSION

The critical thinking skills test data and student post-test results in this study were used to examine the effect of critical thinking skill categories on students' cognitive learning outcomes. Data analysis in this research was conducted through several stages. First, prerequisite hypothesis tests were performed, including normality tests and homogeneity tests. After completing the prerequisite tests, hypothesis testing was conducted to compare post-test scores between both classes based on high and low critical thinking skill categories. The critical thinking skills test was administered before treatment, while the post-test was conducted after treatment in the sample classes. The results of the normality test calculations are presented in Table 1.

Table 1. Normality test results for both classes

Group	Calculated L-value	Critical L-value	Conclusionn
Eksperimen	0.1309	0.1477	Normally distributed
Kontrol	0.1351	0.1477	Normally distributed

Based on Table 1, the experimental class had a calculated L-value of 0.1309 compared to the critical L-value of 0.1477, while the control class showed a calculated L-value of 0.1351 against the same critical value of 0.1477. This confirms that both classes were normally distributed. The homogeneity test results are presented in Table 2 as follows:

Table 2. Homogeneity test results for both classes

Group	χ^2-calculated	χ^2-table	Conclusionn
Eksperimen-Control	0.1883	3.84	Homogeneous

The χ^2-calculated value (0.1883) was below the critical χ^2-value (3.84), confirming both classes were homogeneous. After verifying normality and homogeneity assumptions, we conducted hypothesis testing. The statistical results are presented in Table 3.

Table 3. Two-Factor Analysis of Variance (ANOVA) Summary for Balanced Cells

Source	SS	df	MS	F-cal	F-crit
Learning Media (A)	88.889	1	88.889	0.504	3.981896
Critical Thingking (B)	2450	1	2450.000	13.896	3.981896
Interaction AB	22.222	1	22.222	0.126	3.981896
Error	11988.89	68	176.307	-	-
Total	14550	71	-	-	-

Statistical analysis using SPSS software yielded an F-ratio of 13.896, significantly higher than the critical F-value of 3.981896. This result led to the rejection of the null hypothesis and acceptance of the alternative hypothesis, indicating a statistically significant difference in cognitive learning outcomes between students with high and low critical thinking skills in dynamic fluid mechanics.

Post-ANOVA analysis revealed marginal means of 85.00 for the high critical thinking group compared to 73.34 for the low critical thinking group.

Critical thinking skills play a crucial role in physics learning, particularly in the topic of dynamic fluids, which involves dynamic concepts such as fluid flow, Bernoulli's principle, and the continuity principle. Students with better critical thinking skills tend to grasp phenomena like fluid flow through pipes or channels more easily and can connect physics concepts to real-life situations, such as explaining how Bernoulli's principle applies to airplanes. This finding aligns with Johnson's (2002:185) view that the essence of critical thinking is to achieve comprehensive understanding. This means that strong critical thinking skills promote optimal outcomes, including cognitive learning achievements. This is reinforced by Husnah (2017), who found that critical thinking skills contribute 82.7%, with high critical thinking contributing 85.0% to learning outcomes—indicating a very strong influence—while low critical thinking contributes only 1%, showing a minimal effect.

Additionally, the findings of Ambarwati et al. (2024) show that the experimental class had an average critical thinking score of 75.12 and a conceptual understanding score of 80.12, higher than the control class, which averaged 57.16 in critical thinking and 63.28 in conceptual understanding. This indicates that students with high critical thinking skills also possess strong conceptual understanding, and vice versa. Based on the research of Rahmadani et al. (2022), students with high conceptual understanding also achieve high learning outcomes. Thus, it is evident that students' critical thinking ability plays a vital role in improving cognitive learning outcomes. Saparuddin et al. (2021) also reported a significant correlation between critical thinking skills and learning outcomes, with a significance value of $p < 0.05$. Azzura and Sulaiman (2022) found that critical thinking skills significantly influence learning outcomes, contributing 39.9%. Although this study does not specifically discuss dynamic fluids, the findings demonstrate that critical thinking skills generally enhance students' mastery of learning materials requiring in-depth analysis and the application of complex concepts, as seen in physics topics.

Therefore, this study's findings are consistent with previous results affirming that the level of critical thinking ability is a key factor contributing to cognitive learning achievement, particularly in the topic of dynamic fluid physics.

CONCLUSION

Following the treatment implementation, students with high and low critical thinking skills demonstrated differences in cognitive learning outcomes for the dynamic fluids topic. In studying dynamic fluids, students with higher critical thinking skills consistently achieved better cognitive learning outcomes compared to those with lower critical thinking skills. Conversely, students with weaker critical thinking skills tended to show poorer cognitive achievement. The marginal mean score for high critical thinking students was 85.00, while their low critical thinking counterparts averaged 73.34. These results conclusively demonstrate that students' critical thinking ability significantly influences cognitive learning outcomes in dynamic fluids..

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