Analysis of Critical Thinking Skills in Static Fluid Material with a Contextual Approach for High School Students

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This research intends to examine critical reasoning abilities in stationary liquid substances within high school education. To achieve this goal, this study used a contextual test that incorporates real events into the scientific reasoning process. Using a quantitative descriptive approach, this study included 72 students in grade XII of SMA Negeri 9 Surabaya. To support the analysis, this research gathered information from an assessment of critical thinking skills that is founded on the five Ennis indicators. In addition, to support the analysis, interviews with teachers and a non-test questionnaire were used. The results indicated that the students' critical thinking skills were still considered to be at a low level; indicator achievement ranged between 50.28% and 55.28%, with the strategy and tactics indicator being the highest and the inference indicator the lowest. The results indicated that students were not yet accustomed to interpreting data, evaluating concepts, and drawing scientific conclusions in the context of static fluids. By using the five Ennis indicators applied to static fluid material and presented in a real-world context, this study is updated by analyzing each component of critical thinking skills. This differs from previous research that indicated that students were not yet accustomed to doing this. The research findings also have a significant impact on physics learning, particularly in terms of the need to develop contextually based interactive learning media that enhance thinking skills. In order to more effectively improve students' skills in critical thinking, it is suggested that this study be broadened by developing and evaluating additional educational materials.
Keywords: Critical Thinking Skills, Contextual, Static Fluid, Physics Learning

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1. Introduction

Physics is a discipline that explores different natural occurrences through a structured and rational methodology (Mafarja et al., 2022). Physics is also a field of study that helps students learn to think critically by examining concepts and arguing scientifically. This is because this field of study focuses on exploring natural phenomena (Leshko, Yablon, & Hasiuk, 2025). In the twenty-first century, students are expected to actively participate in their educational journey by engaging in different tasks that assist them in cultivating more advanced and thorough analytical skills (Rehman et al., 2024). According to Tawfik et al. (2023), the study of physics plays an essential role in enhancing higher-level thinking abilities like metacognition, analytical reasoning, and grasping fundamental ideas. This aligns with the current education system's need to offer instruction that is relevant to the demands of the modern era. Mastering the principles of physics and applying them in everyday life requires critical thinking skills (Suprapto et al., 2024). Studies show that students often have weak critical thinking abilities when they are learning physics (Rizki et al., 2024).

Numerous research efforts have discovered that Students in the physics field are not developing enough critical thinking skills (Rizki et al., 2025). These research findings suggest that learning approaches focus

more on memorization than on understanding the fundamental concepts of the subject (Tereshchuk et al., 2023). Furthermore, critical thinking skills are strongly linked to scientific reasoning, as both emphasize evidence-based decision-making in complex, multi-factorial scenarios (Chen et al., 2021). Teacher-focused learning approaches can make it hard for students to grasp how physics concepts work (Faridi et al., 2021). Studies show that when media and teaching methods don't match what schools aim to teach, students don't fully develop their drive, curiosity, success, and ability to think critically (Asrizal et al., 2024). This scenario indicates that there is a necessity to conduct a comprehensive assessment of students' analytical abilities in these areas.

Static fluids are also an important part of physics learning because they are highly contextual and closely related to everyday human life (Saregar et al., 2020). To understand this subject, students need to connect physics ideas with real-life situations (Sujanem & Putu Suwindra, 2023). Critical thinking skills are important because they help students understand how to look at information and decide what is true or useful (Haris & Mahir, 2025). Drawing logical conclusions from physical phenomena occurring in static fluids is also an essential part of learning (Misbah et al., 2024). Therefore, developing critical thinking skills is an essential part of modern science education. This is done with the aim of providing students with the skills to adapt and think critically about challenges that exist worldwide (Marisda et al., 2024).

Critical thinking skills are important for learning physics in the 21st century (Makhrus et al., 2025). Contextual testing is a useful method for evaluating and improving these skills so that students can apply these ideas to real-world situations (Rohman et al., 2024). Studies indicate that using a contextual method in education helps students improve their ability to think critically by connecting what they learn in theory with how they can use that knowledge in real-life situations (Wibowo, 2023). Research also suggests that a contextual approach can enhance students' critical thinking skills (Dessie et al., 2024). This suggests that research-based assessment instruments can describe the quality of scientific reasoning in a more structured manner (Geschwind et al., 2024). Therefore, students' critical thinking skills should be analyzed using contextual testing in physics learning.

Most previous research has focused on conceptual reinforcement rather than measuring critical thinking skills. Skills-based laboratory learning, which encourages procedure design, data evaluation, and evidence-based decision-making, has been demonstrated to assist learners in enhancing their critical thinking abilities rooted in evidence (Walsh et al., 2022). According to Ennis, the five elements include foundational explanation, initial assistance, drawing conclusions, additional clarification, and the formulation of strategies. Each section describes a phase of reasoning, from conceptual understanding to the skills of evaluating and designing scientific solutions. For example, research conducted by (Haris & Mahir, 2025; Makhrus et al., 2025; Suprapto et al., 2024) did not succeed in assessing the overall advancement in critical reasoning abilities through a particular educational framework. Physics methods such as thermodynamics, for example, are effective in helping students develop their ability to think critically. This is because this approach can only track progress in one specific measurement. Physics techniques such as thermodynamics have been shown to help students think critically. Through the use of this approach, students are encouraged to make assumptions, evaluate answers, and relate theory to real-world situations (Marnita et al., 2020). Experiments supported by instrument interface systems and technological tools in physics teaching can also help improve critical thinking skills and assist students in solving problems related to physics concepts in everyday life. This has been demonstrated by introspective and interactive exploration processes (Ramadhan et al., 2023). Previous research has also emphasized inquiry-based learning models rather than improving critical thinking skills (Sujanem & Putu Suwindra, 2023).

Furthermore, rather than studying each aspect of critical thinking specifically, research (Mardiana et al., 2025; Sebastian & Kuswanto, 2025) has concentrated on the impact of media or electronic modules in enhancing critical thinking abilities overall. However, analyzing each element is crucial to identify areas of students' critical thinking processes that are lacking. The contextual nature of the material studied presents additional limitations. Most previous studies have focused on general topics or materials such as thermodynamics and rotational dynamics (Sebastian & Kuswanto, 2025; Taufiq, 2020), It is uncommon to come across studies that examine students' critical thinking skills using Ennis's five aspects, especially when the subject matter is static fluid, which is similar to things we encounter and deal with on a regular basis (Mansyur et al., 2022; Misbah et al., 2024; Saregar et al., 2020). However, research that specifically analyzes students' critical thinking skills contextually in static fluid material is still limited.

Therefore, research specifically analyzing students' critical thinking skills with reference to heat and temperature is not much (Ennis, 1996). This study is very important to obtain further information about students' critical thinking skills, especially to identify the strengths and weaknesses of each component. Contextual assessments serve to evaluate learners' skills in critical reasoning regarding contextual physics ideas. This study looks at how well high school students show their ability to think critically in grasping the notions of heat and temperature as they relate to daily experiences. With this background in mind and noting the variances, the challenge encountered by the researcher.

2. Method

This research method is a quantitative descriptive technique, selecting a total of 72 students from the larger population as a saturated sample to guarantee that the gathered information accurately represented the real circumstances. The quantitative method aims to examine the research sample through collected numerical data, which is subsequently examined through statistical methods, allowing for the assessment of each person to derive a comprehensive picture of critical thinking skills (Charli et al., 2022). The quantitative method seeks to investigate the research subjects by utilizing gathered numerical information, which is subsequently evaluated through statistical methods. This method has a limited population (Darmaji et al., 2022). The researchers directly observed the learning process and conducted critical thinking skills tests, interviews, and questionnaires to obtain primary data (Susetyarini & Fauzi, 2020).

To determine the critical thinking skills of 12th-grade students at SMAN 9 Surabaya studying static fluid physics, the developed instrument was tested on 64 students. The instrument data results were then assessed to determine the level of critical thinking skills. Student score tables from the test instruments and arguments from primary and secondary data sources support the conclusions. This method selected 64 students for the study. The test results were then processed to evaluate the students' critical thinking skills. A quantitative research strategy consisting of several steps is shown here (Charli et al., 2022).

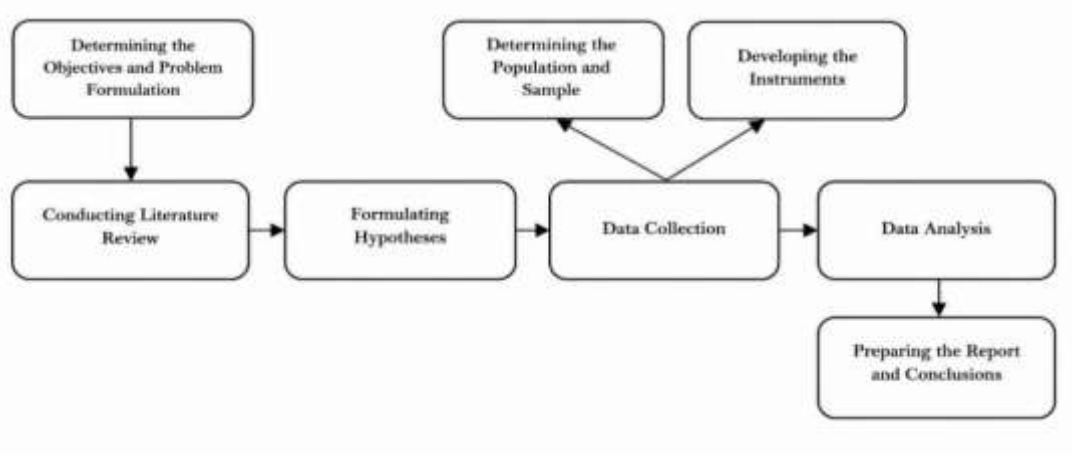


Figure 1. Research Design

Critical thinking skills were used to collect data. According to Ennis, the five characteristics of critical thinking skills are as follows: (1) Elementary Clarification; (2) Basic Support; (3) Inference; (4) Advanced Clarification; and (5) Strategy and Tactics (Abidin et al., 2020). For physics learning, the test instrument also met the criteria for critical thinking. Critical thinking skill indicators for static fluids were used to develop the critical thinking skill instrument (Setiana et al., 2021). This test uses one critical thinking indicator for each question, and the scores are shown in the following table:

Table 1. Question Types: Critical Thinking Skill Indicators

No	Indicator	Information	Scores
1	Elementary Clarification	Explain basic concepts or principles scientifically.	15
2	Basic Support	Provide logical reasons and scientific support for a statement.	20
3	Inference	Draw conclusions based on data, patterns, or empirical evidence.	20
4	Advanced Clarification	Evaluate and clarify the application of concepts to complex situations.	25
5	Strategy and Tactics	Develop strategies or solutions to solve real-life scientific problems.	20

The research data was analyzed quantitatively using descriptive statistics. Percentages were used to measure students' critical thinking skills. The research data analysis was conducted as follows:

$$P = \frac{S}{S_{max}} \times 100\%$$

Description:
P = Percentage
S = Score
S_{max} = Maximum Score

After students' scores are converted to percentages, they are placed into five achievement categories to assess their critical thinking skills.:

Table 2. Categories of Percentage of Achievement of Critical Thinking Skills

Interpretation (%)	Category
$81{,}25 < X \leq 100$	Very high
$71{,}50 < X \leq 81{,}25$	Tall
$62{,}50 < X \leq 71{,}50$	Currently
$43{,}75 < X \leq 62{,}50$	Low

Interpretation (%)	Category
$0 < X \leq 43{,}75$	Very Low

(Hidayatullah et al., 2019)

The results of the instrument test scores will indicate the extent to which students can handle physics problems using critical thinking skills on the topic of waves and their characteristics.

3. Results And Discussion

Instrument Validity and Reliability Test

Before administering a critical thinking skills test, the test instrument must be tested for validity to ensure it is suitable for measuring students' thinking skills. Item analysis is conducted to test the validity of each question item. To assess validity, the scores for each question are corrected. This method is used to assess validity, analyzed using the Product-Moment (Pearson's Correlation) technique with the help of Statistical Product and Service Solution (SPSS).

Table 3. Critical Thinking Skills Test Instrument Validity Results

Question Items	R count	R table	Description.
1	0,5240	0,3017	Valid
2	0,6800	0,3017	Valid
3	0,8220	0,3017	Valid
4	0.4630	0,3017	Valid
5	0,6720	0,3017	Valid

The data in Table 3 indicates that for a total of 64 students, the significance level is 0.3291. Therefore, from this table, all test items are considered valid by comparing the calculated r > the table r.

The reliability of the critical thinking skills test instrument was analyzed using Cronbach's Alpha. The results of the critical thinking skills test instrument reliability test are presented in Table 4.

Table 4. Results of the Critical Thinking Skills Test Instrument Reliability Test

Cronbach's Alpha	N of items
0,643	5

An instrument is considered reliable if the Cronbach's Alpha value is >0.6. Table 4 shows a value of 0.643 for 5 items. This indicates that the critical thinking skills test instrument is reliable, meaning it can consistently measure the critical thinking skills indicators.

Discussion

The results of the critical thinking skills test of grade XII students at SMA N 9 Surabaya on the topic of static fluids are based on the five critical thinking indicators in Ennis's theory: elementary clarification, basic support, inference, advanced clarification, and strategy and tactics. Both test and non-test results were evaluated quantitatively and descriptively. Research data indicates that students have different skills. These results are obtained from how students answered the critical thinking skills test, which includes components of the critical thinking skills indicators.

Elementary clarification: Students are asked to explain basic concepts or principles scientifically in statements.

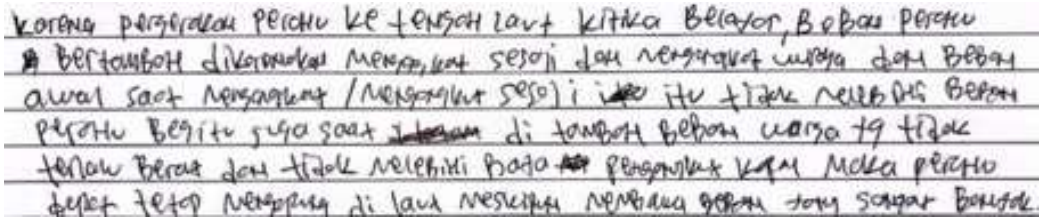


Figure 2. Example of Student Answers for the Elementary Clarification Indicator

Based on the results of student answers for the Elementary Clarification indicator, it appears that many students only wrote descriptive answers. Students did not mention the physics concepts of buoyancy, fluid displacement, and Archimedes' Law. This could be because in previous lessons, students often used memorization methods. The lack of observation of real-world phenomena made it difficult for students to explain the causes and effects of these phenomena. Furthermore, students were not accustomed to writing scientific explanations. The low achievement rate for the Elementary Clarification indicator, at 54.40%, indicates that students' conceptual understanding remains factual and has not yet reached a good level of scientific classification. This situation aligns with a previous study (Faridi et al., 2021), where students tended to memorize concepts without being able to explain them in real-world contexts. The weakness of this basic indicator also contributed to the low performance of other indicators that require conceptual mastery as a foundation for advanced critical thinking and indicates a lack of strong understanding of basic concepts. Basic Support: Students are asked to provide logical reasons and scientific support for a statement.

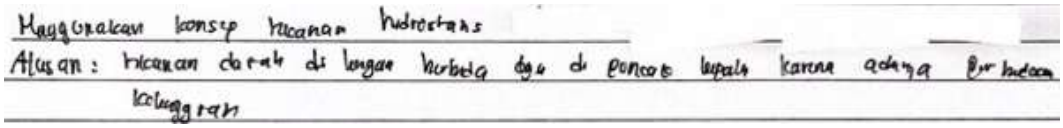


Figure 3. Example of Student Answers for the Basic Support Indicator

Based on the results of students' answers to the Basic Support indicator, the percentage of results for the Basic Support indicator of 51.60% also indicates low ability because students only mentioned the concept of hydrostatic pressure without providing logistical reasons supported by calculations or interpretations of the relationship between physical variables such as density and depth. Students did not explain the relationship between ρ, g, and h to blood pressure. This may occur because students tend to use template answers from textbooks. Students do not engage in activities such as contextual practice questions. Students have not been able to explain why phenomena occur, and are only accustomed to applying formulas mechanically. This incident is in line with previous research (Makhrus et al., 2025), where participants expressed difficulty connecting mathematical representations with their physical meaning. Weaknesses in this aspect indicate low scientific argumentation skills and weak skills in providing evidence support for a statement. The relationship between this indicator and critical thinking skills is that this indicator is the foundation of argumentation skills. If this indicator is weak, then inference and evaluation are also automatically low.

Inference, students *are asked to draw conclusions based on data, patterns, or empirical evidence..*

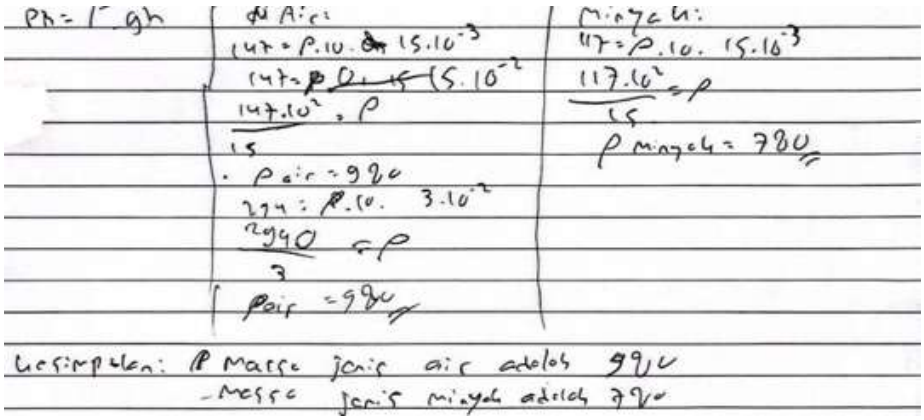


Figure 4. Example of Student Answers on the Inference Indicator

Based on the image above, which is the answer in the Inference indicator, it can be seen that the indicator achievement is classified as the lowest at 46.40%, which requires students to draw conclusions based on empirical data. Most students only calculate hydrostatic pressure without interpreting the relationship pattern between pressure, depth, and fluid density. Students have not been able to generalize information and reason correlations between data in tables, so they cannot provide appropriate scientific conclusions. So this is related to the previous study (Suprapto et al., 2024), namely the Inference indicator is also low, because this indicator is one of the most difficult parts of critical thinking skills because it requires in-depth analysis skills and integration of concepts and data. Low scores on this indicator indicate that students are not yet accustomed to conducting scientific reasoning and have not been trained to read data tables and use practical data comprehensively. The relationship between the Inference indicator and critical thinking skills is because it is one of the highest indicators in the hierarchy of critical thinking skills according to Ennis (1996). Thus, although students may have a superficial understanding of the material, their skills in applying logical reasoning, connecting concepts, and drawing systematic conclusions are still limited, resulting in underdevelopment of more complex aspects of critical thinking (Barta et al., 2022). Low scores indicate underdeveloped scientific analysis skills.

Advanced Clarification: Students are asked to evaluate and clarify the application of concepts to complex situations.

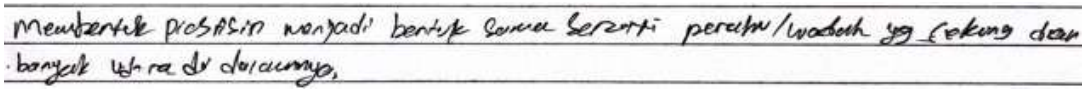


Figure 5. Example of Student Answers for the Advanced Clarification Indicator

Based on the figure above, the Advanced Clarification indicator shows that students were unable to accurately relate the concept of fluid pressure to the context of evaluating dam structures. This indicator yielded a percentage of 54.90%. Students were only able to answer descriptively about dam design without providing supporting physical explanations, for example, that the greatest pressure is at the base of the dam due to the depth of the fluid. This may occur because students lack practice solving open-ended problems. Students are not accustomed to evaluating real-world concepts. Students tend to provide technical answers without scientific evaluation, resulting in low Advanced Clarification skills. This study also aligns with previous research on critical thinking skills (Misbah et al., 2024), which states that evaluation skills carried out in complex situations require scientific reasoning-based practice, which has been lacking in physics instruction, which focuses solely on memorization. The Advanced Clarification indicator is related to critical thinking skills because this indicator indicates the level of assessing, evaluating, and validating

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scientific arguments. Low scores also indicate that students have not mastered higher-level critical thinking skills.

Strategy and Tactics, students are asked to design strategies or solutions to solve real scientific problems.

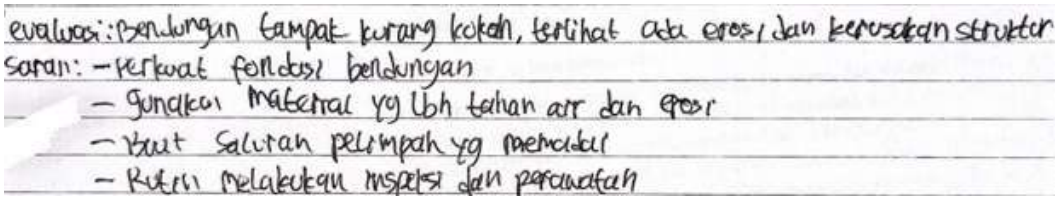


Figure 6. Example of Student Answers for the Strategy and Tactics Indicator

Based on the results of student answers for the Strategy and Tactics indicator, it appears that students achieved the highest achievement compared to other indicators, at 51.50%, although this is still in the low category. Students were able to provide creative solutions, such as changing the shape of plasticine so that it floats, but were unable to explain the scientific reasons for the increase in total volume, decrease in average density, and increase in buoyancy in Archimedes' Law. The high percentage on this indicator may have occurred because it demonstrates that applicative and contextual tasks are easier for students to understand because they are close to real-life experiences. The indicators in this question are similar to experiments, making it easier for students to understand the questions. Research on this indicator aligns with previous studies (Dessie et al., 2024), which found that real-world contexts can enhance students' creativity and problem-solving skills, even if their reasoning is still not in-depth.

Thus, from the results of student answers on the Strategy and Tactics indicator, it can be seen that students obtained a percentage of this indicator of 51.50%. Where students did not explain the relationship between fire and physics concepts scientifically, students only mentioned heat transfer. Furthermore, the strategy provided by students was correct, but not quite precise and was only a general strategy, not connected to physics concepts. From the results of the test of students' critical thinking skills, the average percentage of each indicator can be seen in Figure 6.

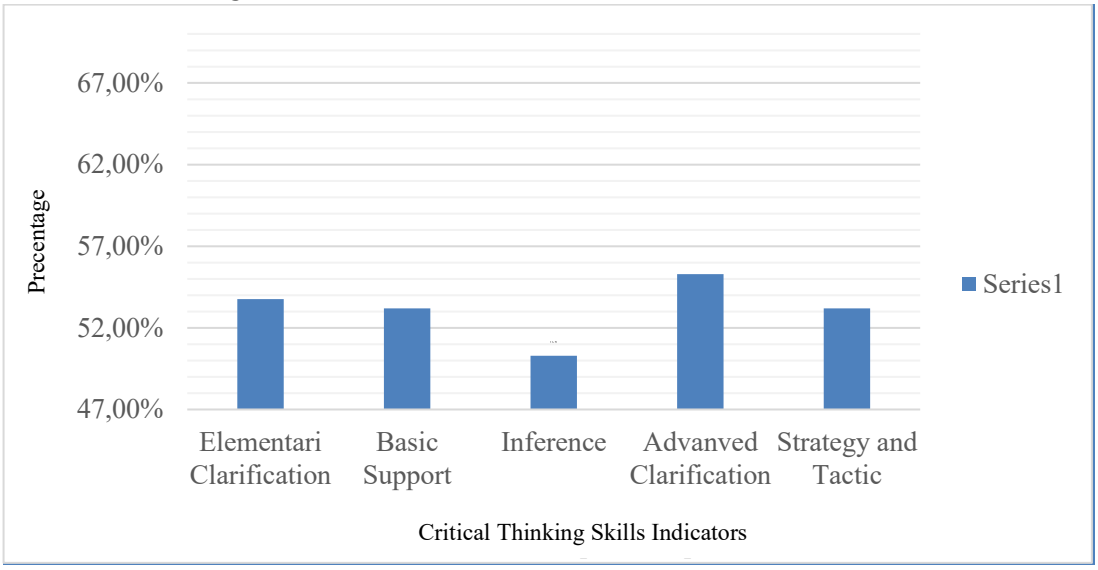


Figure 7. Percentage Diagram of Students' Critical Thinking Skills

The highest percentage for this indicator may occur because it shows that applied and contextual tasks are easier for students to understand because they are close to real-life experiences. The indicator in this question is similar to an experiment, which makes it easier for students to understand the questions. Research on this indicator aligns with previous studies (Dessie et al., 2024), which found that real-world

contexts can enhance students' creativity and problem-solving skills, even though their reasoning is still not in-depth. Based on the categories, the students' critical thinking skills can be explained by category, as shown in the following table:

Table 5. Description of Students' Critical Thinking Skills by Category

Category	Interpretation (%)	Frequency
Very High	$86 \leq P \leq 100$	0
High	$74 \leq P \leq 85$	0
Fair	$62 \leq P \leq 73$	11
Low	$50 \leq P \leq 61$	42
Very Low	$P \leq 49$	19

A small percentage of students, with no students in the high or very high categories, demonstrates that no students were able to consistently provide scientific reasoning, logical argumentation, and contextual solutions. In the sufficient category, there were 11 students (28.95%), indicating that some students were beginning to apply concepts and draw conclusions correctly, but their performance across all critical thinking indicators was not yet stable. Furthermore, 42 students (65.63%) were in the low category, indicating that many students felt unable to explain concepts, interpret data, and provide accurate scientific evaluations. Furthermore, 19 students (26.39%) were categorized as very low, indicating that they were unable to understand basic concepts or solve critical thinking problems. Overall, the distribution of these categories demonstrates that students' critical thinking skills are still dominated by the low category, in line with the overall average achievement of 53.14%, which can be considered insufficient. Therefore, learning interventions are needed to improve students' analytical, evaluation, and scientific reasoning skills. The overall average score obtained by students, differentiated by each question's indicator and its respective maximum score. The complete results are presented in the table below.

Table 6. Overall Analysis of Students' Critical Thinking

Question Number	Total Score Obtained	Average Score	Precentage
1	774	10,75	53,75%
2	766	10,64	53,19%
3	724	10,06	50,28%
4	796	11,06	55,28%
5	766	10,64	53,19%

When completing the critical thinking skills test, which consisted of five questions that matched the critical thinking skills in the questions, students experienced difficulty finding answers.

In general, the cause of students' low critical thinking skills is a learning system that relies solely on teachers and is oriented towards memorizing formulas. Students are not accustomed to connecting physics concepts to everyday phenomena, resulting in suboptimal scientific reasoning development. Overall, the results of this study indicate that contextual tests are effective as diagnostic instruments for measuring and stimulating students' critical thinking skills. Physics learning needs to be integrated with real-world contexts where students can apply it in their daily lives, rather than simply understanding it based on theory.

Based on the results of the non-test questionnaire, which included ten statements, it was clear that many students had a positive view of innovative and contextual physics learning. The percentage of student responses can be seen in Table 7 below.

Table 7. Percentage of Student Responses

Statement	Percentage
Are you interested in learning physics using Android?	94,50%
Do you think contextual learning media improves critical thinking skills?	87,90%

Statement	Percentage
Do you think critical thinking skills are important in learning physics?	77,20%
Do you find printed textbooks boring for learning?	71,30%
Do you support learning physics through lab work?	97,50%
Do you believe contextual and interactive learning media are necessary?	83,30%
Do you find Static Fluids difficult to understand?	93,40%
Do you think Static Fluids is important to learn?	87,20%
Do you have difficulty understanding physics concepts?	87,40%
Are you interested in learning physics at school?	76,70%

A total of 97.50% of students supported physics learning accompanied by practical work and fun activities, as they were considered to facilitate the process of understanding concepts. In addition, 83.30% of students stated the need for the use of interactive, digital-based contextual learning media, which can make learning activities interesting and easier to understand. Meanwhile, 87.20% of students considered static fluid material important to learn, although 87.40% of them still found the concept difficult to understand. These results indicate a gap between awareness of the importance of the material and the level of understanding possessed by students. A total of 71.30% of students also considered conventional printed textbooks boring because they lack interactivity, while 77.20% of students recognized the importance of critical thinking skills in learning physics. Overall, the data indicates that students need more contextual, interactive, and digital-based learning to increase conceptual understanding and train their critical thinking skills. The percentage of student response questionnaire results can be clearly seen in Figure 8 below.

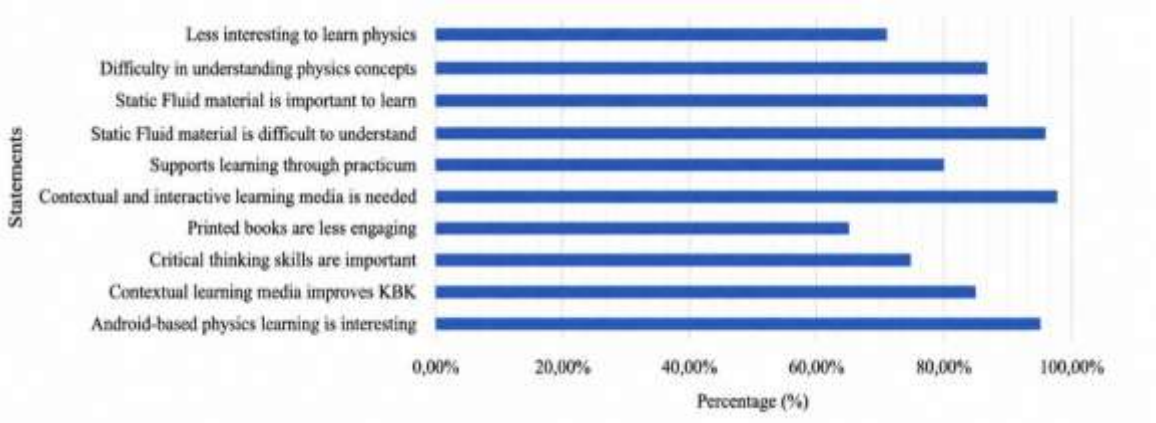


Figure 8. Student Questionnaire Results Diagram

According to interviews conducted with physics teachers at SMA Negeri 9 Surabaya, it was found that only a few students were able to think critically, and this was considered to be a relatively low level. The teacher stated that most students simply memorized formulas but did not understand their conceptual meaning or explain the scientific reasons behind physical phenomena. The weakest critical thinking indicators were in the analysis and evaluation aspects, as students were not yet accustomed to reasoning and verifying concepts scientifically. One of the main causes was the teaching and learning process relying solely on teachers and the limited use of interactive media to encourage students to think more reflectively and exploratively. The teacher also revealed that the short learning time resulted in students rarely engaging directly in experimental activities that could stimulate critical thinking. Therefore, the teacher strongly encouraged the development of interactive, digital-based, contextual learning media, as they believed they could help students visualize abstract concepts, increase learning engagement, and develop critical thinking skills through more active and engaging learning activities. Research has shown that improving students' critical thinking skills is interrelated with the application of technology-based learning strategies and scientific approaches that require higher-order thinking activities. Several articles analyzed on the same

topic have found relevant research findings that demonstrate the importance of learning in improving critical thinking skills. Furthermore, teachers who develop learning media also support student engagement. Research suggests that a reciprocal teaching approach significantly improves critical thinking skills in physics because it encourages students to ask questions, predict, and evaluate arguments reflectively (Mafarja et al., 2022). A teaching and learning process that emphasizes experimental skills strengthens critical thinking skills compared to traditional laboratories that only emphasize concepts (Walsh et al., 2022). Furthermore, the limited use of interactive learning media, such as Android-based applications, is also a factor that hinders the development of students' critical thinking skills (Isnaeni et al., 2022). Similar results also indicate that the use of learning media utilizing AR (augmented reality) can significantly improve students' critical thinking skills. AR allows students to see concepts and be actively involved in the learning process (Dewi & Kuswanto, 2023).

4. Conclusion

The results of the study indicate that students' critical thinking skills are lacking in static fluid material. This study indicates that students are not yet accustomed to interpreting data, making scientific arguments, and drawing logical conclusions from real-world situations. The causes are teacher-centered learning, minimal use of learning media, and a lack of contextual activity materials that represent real situations for students. Therefore, there is an urgency to implement contextual-based interactive learning media that can visualize static fluid concepts concretely, facilitate exploratory activities, and stimulate students' critical thinking skills to be optimal. The limitations of this study are the number of samples in one school and the absence of specific learning interventions. The study only focused on analyzing critical thinking skills without testing the effectiveness of specific learning models or media. Therefore, for further research, researchers are expected to develop teaching and learning media on a broader scope. By using interactive learning media based on contextual problems to improve students' critical thinking skills in static fluid material, researchers are expected to provide comprehensive information about these efforts.

5. References

Abidin, A. Z., Istiyono, E., Fadilah, N., & Dwandaru, W. S. B. (2020). A computerized adaptive test for measuring the physics critical thinking skills. *International Journal of Evaluation and Research in Education*, *8*(3), 376–383. https://doi.org/10.11591/ijere.v8i3.19642

Asrizal, Nazifah, N., Effendi, H., & Helma. (2024). STEM-Smart Physics E-Module to Promote Conceptual Understanding and 4C Skills of Students. *International Journal of Information and Education Technology*, *14*(2), 279–286. https://doi.org/10.18178/ijiet.2024.14.2.2049

Barta, A., Marzano, G., & Cuomo, M. T. (2022). The development of students' critical thinking abilities and the effectiveness of concept-mapping vs traditional teaching: A meta-analysis. *Thinking Skills and Creativity,* 44, 101024. https://doi.org/10.1016/j.tsc.2022.101024

Charli, M. S., Eshete, S. K., & Debela, K. L. (2022). Learning How Research Design Methods Work: A Review of Creswell's Research Design: Qualitative, Quantitative and Mixed Methods Approaches. *The Qualitative Report*. https://doi.org/10.46743/2160-3715/2022.5901

Chen, X., Kuo, H.-C., & Brookes, D. T. (2021). *Exploring and supporting student reasoning in physics by leveraging dual-process theories of reasoning and decision making.* Physical Review Physics Education Research, 17(1), 010128. https://doi.org/10.1103/PhysRevPhysEducRes.17.010128

Darmaji, D., Astalini, A., Kurniawan, D. A., & Putri, W. A. (2022). Science Process Skills and Critical Thinking Ability Assessed from Students' Gender. *Jurnal Pendidikan Fisika Indonesia*, *18*(1), 83–95. https://doi.org/10.15294/jpfi.v18i1.30534

Dessie, E., Gebeyehu, D., & Eshetu, F. (2024). Motivation, conceptual understanding, and critical thinking as correlates and predictors of metacognition in introductory physics. *Cogent Education*, *11*(1). https://doi.org/10.1080/2331186X.2023.2290114

Dewi, P. S., & Kuswanto, H. (2023). THE EFFECTIVENESS OF THE USE OF AUGMENTED REALITY-ASSISTED PHYSICS E-MODULE BASED ON PEDICAB TO IMPROVE MATHEMATICAL COMMUNICATION AND CRITICAL THINKING ABILITIES. *Journal of Technology and Science Education*, *13*(1), 53–64. https://doi.org/10.3926/jotse.1714

Faridi, H., Tuli, N., Mantri, A., Singh, G., & Gargrish, S. (2021). A framework utilizing augmented reality to improve critical thinking ability and learning gain of the students in Physics. *Computer Applications in Engineering Education*, *29*(1), 258–273. https://doi.org/10.1002/cae.22342

Geschwind, G., et al. (2024). Using a research-based assessment instrument to explore undergraduate students' proficiencies around measurement uncertainty in physics lab contexts. *Physical Review Physics Education Research,* *20*(2), 020105. https://doi.org/10.1103/PhysRevPhysEducRes.20.020105

Haris, A., & Mahir. (2025). The Influence of Problem-Solving-Based Physics Learning Models on Students' Critical Thinking Ability and Learning Independence on the Achievement of SDG 4. *International Journal of Learning, Teaching and Educational Research*, *24*(8), 1076–1091. https://doi.org/10.26803/ijlter.24.8.48

Hidayatullah, M. S., Zawawi, I., Khikmiyah, F., & Gresik, U. M. (2019). *KETERAMPILAN BERPIKIR KRITIS PESERTA DIDIK DALAM MENYELESAIKAN MASALAH MATEMATIKA MELALUI MODEL PEMBELAJARAN PROBLEM BASED LEARNING DI KELAS VII SMP NEGERI 1 GLAGAH LAMONGAN* (Muhammad Syarif Hidayatullah & Irwani Zawawi, Trans).

Isnaeni, W., Sujatmiko, Y. A., & Pujiasih, P. (2021). Analysis of the role of Android-based learning media in learning critical thinking skills and scientific attitude. *Jurnal Pendidikan Ilmu-Ilmu,* *10*(4). https://doi.org/10.15294/jpii.v10i4.27597

Leshko, D., Yablon, L., & Hasiuk, I. (2025). The principle of historicism and ways of its implementation in a physics course. *Journal of Vasyl Stefanyk Precarpathian National University,* *12*(1), 96–104. https://doi.org/10.15330/jpnu.12.1.96-104

Mafarja, N., Zulnaidi, H., & Mohd. Fadzil, H. (2022a). Using Reciprocal Teaching Strategy to Improve Physics Students' Critical Thinking Ability. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(1). https://doi.org/10.29333/EJMSTE/11506

Mafarja, N., Zulnaidi, H., & Mohd. Fadzil, H. (2022b). Using Reciprocal Teaching Strategy to Improve Physics Students' Critical Thinking Ability. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(1). https://doi.org/10.29333/EJMSTE/11506

Makhrus, M., Rahayu, S., Santoso, D., & Annam, S. (2025). Effect of E-Module Based on Sustainable Development Goals (SDGs) with Conceptual Change Model-Cognitive Conflict Approach (CCM-CCA) Integrated with Local Wisdom on Students' Critical Thinking Skills. *Educational Process: International Journal*, *17*. https://doi.org/10.22521/edupij.2025.17.399

Mansyur, J., Werdhinana, I. K., Darsikin, D., Kaharu, S. N., & Tadeko, N. (2022). Students' mental models about the suspending objects in static fluid. *Journal of Turkish Science Education*, *19*(1), 257–287. https://doi.org/10.72681/tused.2022.121

Mardiana, N., Maulina, B., Mardiani, N., Sabar, S., & Collantes, L. M. (2025). ENHANCING CRITICAL THINKING SKILLS THROUGH ANDROID-ASSISTED VIRTUAL PHYSICS LEARNING: A FOCUS ON HOTS DEVELOPMENT. *Jurnal Ilmiah Ilmu Terapan Universitas Jambi*, *9*(2), 513–526. https://doi.org/10.22437/jiituj.v9i2.34373

Marisda, D. H., Nurlina, N., Ma'ruf, M., Rahmawati, R., Idamayanti, R., & Akbar, M. (2024). Challenges in secondary school education: profile of physics students' critical thinking skills. *Journal of Education and Learning*, *18*(3), 1099–1106. https://doi.org/10.11591/edulearn.v18i3.21666

Misbah, M., Hamidah, I., Sriyati, S., Samsudin, A., Farahwahidah, N., & Rahman, A. (2024). DEVELOPMENT OF FLUID PHYSICS E-MODULE BASED ON ARGUMENTATION-DRIVEN INQUIRY LABORATORY TO DEVELOP CRITICAL THINKING SKILLS AND PROBLEM-SOLVING ABILITIES IN PROSPECTIVE PHYSICS TEACHERS. In *Journal of Engineering Science and Technology Special Issue on* (Vol. 19, Issue 6).

Rehman, N., Huang, X., Mahmood, A., AlGerafi, M. A. M., & Javed, S. (2024). Project-based learning as a catalyst for 21st-Century skills and student engagement in the math classroom. *Heliyon*, *10*(23). https://doi.org/10.1016/j.heliyon.2024.e39988

Rizki, I. A., Mirsa, F. R., Islamiyah, A. N., Saputri, A. D., Ramadani, R., & Habibbulloh, M. (2025). Ethnoscience-enhanced physics virtual simulation and augmented reality with inquiry learning: Impact on students' creativity and motivation. *Thinking Skills and Creativity*, *57*. https://doi.org/10.1016/j.tsc.2025.101846

Rizki, I. A., Suprapto, N., Saphira, H. V., Alfarizy, Y., Ramadani, R., Saputri, A. D., & Suryani, D. (2024). Cooperative model, digital game, and augmented reality-based learning to enhance students' critical thinking skills and learning motivation. *Journal of Pedagogical Research*, *8*(1), 339–355. https://doi.org/10.33902/JPR.202423825

Rohman, M. H., Marwoto, P., Nugroho, S. E., & Supriyadi, S. (2024). Effectiveness of Ethnoecological-STEM Project-Based Learning Model to Improve Critical Thinking Skills, Creativity, and Science Concept Mastery. *International Journal of Cognitive Research in Science, Engineering and Education*, *12*(3), 521–534. https://doi.org/10.23947/2334-8496-2024-12-3-521-534

SAREGAR, A., LATIFAH, S., HUDHA, M. N., SUSANTI, F., & SUSILOWATI, N. E. (2020). Stem-inquiry brainstorming: Critical and creative thinking skills in static fluid material. *Periodico Tche Quimica*, *17*(72), 491–505. https://doi.org/10.52571/ptq.v17.n72.2020.506_periodico72_pgs_491_505.pdf

Sebastian, R., & Kuswanto, H. (2025). The effectiveness of a physics e-book on rotational dynamics of a traditional top game assisted by augmented reality to improve students' critical thinking skills and visual representations. *Revista Mexicana de Fisica E*, *22*(2). https://doi.org/10.31349/RevMexFisE.22.020205

Setiana, D. S., Purwoko, R. Y., & Sugiman. (2021). The application of mathematics learning model to stimulate mathematical critical thinking skills of senior high school students. *European Journal of Educational Research*, *10*(1), 509–523. https://doi.org/10.12973/EU-JER.10.1.509

Sujanem, R., & Putu Suwindra, I. N. (2023). PROBLEM-BASED INTERACTIVE PHYSICS E-MODULE IN PHYSICS LEARNING THROUGH BLENDED PBL TO ENHANCE STUDENTS' CRITICAL THINKING SKILLS. *Jurnal Pendidikan IPA Indonesia*, *12*(1), 135–145. https://doi.org/10.15294/jpii.v12i1.39971

Suprapto, N., Rizki, I. A., & Cheng, T. H. (2024). Profile of Students' Physics Critical Thinking Skills and Prospect Analysis of Project-Oriented Problem-Based Learning Model. *Journal of Educational and Social Research*, *14*(3), 134–149. https://doi.org/10.72941/jesr-2024-0062

Susetyarini, E., & Fauzi, A. (2020). Trend of critical thinking skill researches in biology education journals across Indonesia: From research design to data analysis. *International Journal of Instruction*, *13*(1), 535–550. https://doi.org/10.29333/iji.2020.13135a

Taufiq, M. (2020). THE EFFECT OF BLENDED LEARNING PROBLEM-BASED INSTRUCTION MODEL ON STUDENTS' CRITICAL THINKING ABILITY IN THERMODYNAMIC COURSE. *JPII*, *9*(3), 430–438. https://doi.org/10.15294/jpii.v9i3

Tawfik, M., Jiménez, C., Sancristobal, E., Martín, S., & Castro, M. (2023). *Enhancing critical thinking, metacognition, and conceptual understanding in introductory physics: The role of inquiry-based remote laboratories.* Eurasia Journal of Mathematics, Science and Technology Education, 19(6), em2321. https://doi.org/10.29333/ejmste/13273

Tereshchuk, S., Sharov, S., Tereshchuk, A., Kolmakova, V., & Sharova, T. (2023). Critical thinking and hypothetic-deductive scheme for studying the elements of quantum theory. *International Journal of Evaluation and Research in Education*, *12*(3), 1497–1506. https://doi.org/10.11591/ijere.v12i3.25249

Walsh, C., Lewandowski, H. J., & Holmes, N. G. (2022a). Skills-focused lab instruction improves critical thinking skills and experimentation views for all students. *Physical Review Physics Education Research*, *18*(1). https://doi.org/10.1103/PhysRevPhysEducRes.18.010128

Wibowo, F. C. (2023). EFFECTS OF AUGMENTED REALITY INTEGRATION (ARI) BASED MODEL PHYSICS INDEPENDENT LEARNING (MPIL) FOR FACILITATING 21ST-CENTURY SKILLS (21-CS). *Journal of Technology and Science Education*, *13*(1), 178–192. https://doi.org/10.3926/jotse.1800