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The Effect of Problem-Solving Learning Model on Students' Critical Thinking Skills in High School Physics Learning

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Abstract *– Critical thinking is an essential competence in 21st-century physics learning, particularly because students are expected not only to memorize formulas but also to analyze scientific phenomena, evaluate evidence, and construct logical explanations. However, physics instruction in high schools often remains dominated by teacher-centered practices that provide limited opportunities for students to develop higher-order thinking skills. This study aimed to examine the effect of the problem-solving learning model on high school students' critical thinking skills in learning about static fluids. A quantitative, pre-experimental one-group pretest–posttest design was employed. The participants were 24 Grade XI Science students at SMA Negeri 15 Adidarma Banda Aceh, selected through purposive sampling. Data were collected using an essay-based critical thinking skills test developed based on five indicators: elementary clarification, basic support, inference, advanced clarification, and strategy and tactics. The data were analyzed using descriptive statistics, N-Gain, paired sample t-test, Cohen's d, and eta squared. The results showed that students' average critical thinking score increased from 38.33 in the pretest to 80.71 in the posttest, with an average N-Gain of 0.70, categorized as high. The paired-samples t-test indicated a significant difference between pretest and posttest scores ($p = 0.000 < 0.05$). The effect size analysis showed a Cohen's d value of 3.91 and an eta squared value of 0.97, indicating a very strong practical effect. The novelty of this study lies in providing empirical evidence on the application of problem-solving learning in static fluid material. These findings contribute to physics education by confirming that structured problem-solving instruction can effectively promote students' critical thinking and meaningful conceptual understanding.*

Keywords: *critical thinking; high school; physics learning; problem-solving; static fluid*

I. INTRODUCTION

The 21st century has brought rapid developments in science, technology, and society, requiring students to master competencies that go beyond memorizing factual knowledge. One of the most essential competencies in contemporary education is critical thinking, which enables learners to analyze information, evaluate evidence, construct logical arguments, and solve problems in a reasoned manner (Facione, 2011; Hanafi & Doyan, 2024; Sukaria, 2025). In physics education, critical thinking is particularly important because physics involves abstract concepts, mathematical representations, scientific models, and natural phenomena that require students to reason systematically. The dimensions of critical thinking in physics, such as interpretation, analysis, and inference, need to be developed explicitly because they are closely related to students' ability to understand concepts and construct scientific explanations (Marisda et al, 2022; Hanafi & Doyan, 2024; Kassiavera et al., 2024). Without adequate critical thinking skills, students tend to rely on memorizing formulas and definitions rather than developing conceptual understanding and scientific reasoning (Suciono, 2021).

Critical thinking is also closely related to scientific literacy. International assessments such as PISA emphasize that scientific literacy includes the ability to explain phenomena scientifically, evaluate and design scientific investigations, and interpret data and evidence (OECD, 2023). These abilities are aligned with the core components of critical thinking, including analyzing arguments, making inferences, drawing conclusions, and evaluating the validity of evidence. Recent reviews further show that student-centered science and physics learning is needed to help students interpret evidence, construct arguments, and evaluate scientific claims more effectively (Yu & Zin, 2023; Kassiavera et al., 2024). In the Indonesian educational context, students' performance on international assessments indicates a need for stronger instructional efforts to develop higher-order thinking skills. Therefore, physics learning should not only focus on content mastery but also provide opportunities for students to develop reasoning, inquiry, and reflective thinking skills.

The direction of Indonesian education policy also reinforces the importance of this transformation. Through the Merdeka Belajar initiative, the Ministry of Education has encouraged learning practices that move beyond teacher-centered instruction and rote memorization toward deep learning experiences that engage students actively in understanding, analyzing, and applying knowledge (Kemendikbudristek, 2024). Deep learning enables students to connect prior knowledge with new concepts, construct meaningful understanding, and apply scientific reasoning to authentic problems. This orientation is consistent with recent empirical evidence indicating that active physics learning, supported by problem-based tasks, can improve critical thinking, learner autonomy, and meaningful engagement (Nurazmi & Bancong, 2021; Sujanem & Suwindra, 2023; Haris & Mahir, 2025). Thus, Indonesian physics instruction needs to align curriculum implementation with learning models that promote critical thinking, creativity, collaboration, and problem-solving as essential 21st-century competencies for students.

One learning model that is relevant to these demands is the problem-solving learning model. Grounded in constructivist learning theory, this model positions students as active participants in the construction of knowledge through systematic stages of learning. Students are guided to identify problems, analyze relevant information, formulate hypotheses, test possible solutions, and evaluate the results of their reasoning (Jonassen, 2010; Mayer, 2014). Recent systematic reviews on problem-based and problem-solving instruction also report that authentic problems, structured inquiry, and reflective reasoning can stimulate students' critical thinking and problem-solving skills in physics and broader educational contexts (Liu & Pásztor, 2022; Yu & Zin, 2023; Nicholus et al., 2023). These stages are highly compatible with physics learning because they reflect the nature of scientific inquiry, in which students are expected to investigate phenomena, develop explanations, and justify conclusions based on evidence. Thus, the problem-solving learning model has the potential to improve students' conceptual understanding while simultaneously strengthening their critical thinking skills.

In physics classrooms, problem-solving activities can help students understand concepts more meaningfully. Previous studies have shown that students involved in problem-solving-based learning tend to demonstrate better conceptual understanding, stronger engagement, and greater motivation to learn (Puspitawati & Mawardi, 2022; Yusnidar et al., 2023). Recent studies in physics education also report that blended problem-based physics modules and problem-based learning models can enhance students' critical thinking skills, learning independence, and positive responses to learning (Sujanem & Suwindra, 2023; Haris & Mahir, 2025). For example, in learning static fluid concepts, students can be encouraged to analyze phenomena such as floating, sinking, pressure, buoyancy, and Archimedes' principle through observation, reasoning, and evidence-based discussion. Such learning experiences allow students to move beyond rote memorization of formulas and develop a deeper understanding of the relationship between physics concepts and real-life phenomena.

However, physics learning in many Indonesian high schools is still often dominated by conventional instructional practices. Lectures, demonstrations, and teacher-centered assignments tend to emphasize the transmission of knowledge rather than the development of students' thinking processes (Arends, 2018; Saputra et al., 2019). These approaches provide limited opportunities for students to ask questions, analyze problems, justify arguments, or reflect on their learning. Studies on physics learning resources and reasoning-oriented activities in Indonesia also indicate the need to strengthen students' understanding of the nature of science and scientific reasoning in classroom learning (Bancong et al, 2023; Nurazmi & Bancong, 2025). More recent evidence from physics assessment research in Indonesia also indicates that students still exhibit uneven performance across critical-thinking dimensions, highlighting the need for classroom strategies that explicitly train reasoning, interpretation, and evaluation (Kassiavera et al., 2024). As a result, students often struggle to apply physics concepts to new situations, which may lead to shallow learning outcomes and underdeveloped critical thinking skills (Santoso & Arif, 2021).

This condition indicates a gap between the competencies expected by educational policy and the learning practices actually implemented in classrooms.

The problem-solving learning model offers a relevant alternative to address this issue. Its structured learning stages provide opportunities for students to engage actively with learning materials, construct explanations, test ideas, and evaluate solutions. Previous research has reported that problem-solving-based learning can improve higher-order thinking skills and science learning outcomes (Septianingsih et al., 2026). Recent studies strengthen this claim by showing that problem-based and problem-solving-oriented instruction can positively influence students' critical thinking, problem-solving ability, and learning independence, although effectiveness may vary depending on instructional design, intervention duration, group size, and assessment instruments (Liu & Pásztor, 2022; Yu & Zin, 2023; Haris & Mahir, 2025). Nevertheless, empirical studies examining the implementation of this model in specific physics topics, particularly static fluid, remain limited. Static fluid is an important topic because it is closely related to everyday phenomena, yet it is often taught through procedural problem solving and formula application rather than inquiry-based reasoning.

Given this condition, it is necessary to investigate the effect of the problem-solving learning model on students' critical thinking skills in learning about static fluids. This study is important because it provides empirical evidence of the effectiveness of problem-solving instruction in a physics context that is relevant to students' daily experiences. In addition, the findings are expected to offer practical implications for physics teachers in designing learning activities that support higher-order thinking and align with the goals of 21st-century education and the Merdeka Belajar curriculum (Sujanem & Suwindra, 2023; Nicholus et al., 2023; Haris & Mahir, 2025).

Accordingly, this study aims to examine the effect of the problem-solving learning model on improving high school students' critical thinking skills in static fluid physics. The contribution of this study lies in strengthening the empirical basis for the use of active, problem-oriented learning strategies in physics education and in providing practical insights to improve classroom instruction that promotes meaningful learning and scientific reasoning. This contribution also responds to recent calls for physics learning that systematically integrates conceptual understanding, evidence-based reasoning, and problem-solving activities to strengthen students' development of critical thinking.

II. METHODS

This study employed a quantitative pre-experimental design with a One-Group Pretest–Posttest Design. This design was selected because the study aimed to examine the difference in students' critical thinking skills before and after the implementation of the problem-solving learning model in one intact classroom. According to Sugiyono (2013), a pretest–posttest design is appropriate for identifying changes in students' learning outcomes following a specific treatment. Although this design does not involve a control group, it remains relevant for classroom-based research because it allows the researcher to evaluate the effectiveness of an instructional intervention under natural learning conditions. The study design is presented in Table 1.

Table 1. One-group pretest–posttest design

Group	Pre-test	Treatment	Posttest
Experimental	T_1	X	T_2

In Table 1, T1 denotes the initial test administered before the learning process, X denotes the treatment using the problem-solving learning model, and T2 denotes the final test administered after the treatment. The population of this study comprised all Grade XI Science students at SMA Negeri 15 Adidarma, Banda Aceh. The sample was selected using purposive sampling and comprised one intact Grade XI Science class of 24 students. The class was selected because it represented the school's average level of physics achievement based on previous semester records, making it appropriate for describing typical classroom learning conditions.

The instruments used in this study consisted of an observation sheet, a teaching module, and a critical thinking skills test. The observation sheet was used to monitor the fidelity of the implementation of the problem-solving learning model. Two physics teachers were involved as observers to support objectivity and reduce subjectivity in evaluating the implementation process. The teaching module was developed by the researcher to guide the learning process through six phases of the problem-solving learning model: problem identification, problem analysis, hypothesis formulation, data collection, hypothesis testing, and conclusion drawing. These phases are aligned with the nature of problem-solving learning, which emphasizes systematic reasoning, evidence-based decision-making, and reflective thinking. The critical thinking skills test consisted of essay questions developed from five indicators adapted from Suciono (2021): providing simple explanations, building basic skills, drawing conclusions, providing further explanations, and developing strategies and tactics. Essay questions were used because they allow students to express their reasoning processes more comprehensively and provide richer evidence of critical thinking than objective test items (Facione, 2011).

Data collection was conducted in three stages. In the first stage, students were administered a pretest to measure their initial critical thinking skills. In the second stage, the problem-solving learning model was implemented over two consecutive 90-minute meetings. The learning activities focused on static fluid material because this topic contains contextual phenomena such as pressure, buoyancy, floating, and sinking, which require students to analyze problems, evaluate evidence, and draw logical conclusions. During the treatment, the teacher guided students through the problem-solving stages, while the observers recorded the implementation of each phase using the observation sheet. In the third stage, students were given a posttest using the same critical-thinking skills test to measure improvement following the intervention.

Data analysis was conducted quantitatively to examine both statistical and practical significance. The students' pretest and posttest scores were first calculated to obtain the mean achievement of critical thinking skills. Before conducting the paired-sample t-test, the normality of the data was assessed using the Chi-square test, as suggested by Sugiyono (2013). The Chi-square formula used in this study is presented as follows:

$$\chi^2 = \sum_{i=1}^{k} \frac{(oi - Ei)^2}{Ei} \qquad (1)$$

where $\chi2$ is the Chi-square statistic, Oi is the observed frequency, and Ei is the expected frequency. If the data were normally distributed, a paired sample t-test was conducted to determine whether there was a significant difference between the pretest and posttest scores. The paired sample t-test was appropriate because the same students were measured before and after the intervention. The formula used is presented below:

$$t = \frac{\bar{D}}{\frac{SD}{\sqrt{n}}} \qquad (2)$$

where t is the calculated t-value, $\bar{D}$ is the mean difference between pretest and posttest scores, SD is the standard deviation of the differences, and nn is the number of students.

To determine the practical significance of the intervention, effect size analysis was conducted using Cohen's d and eta squared. Cohen's d was used to determine the strength of the difference between pretest and posttest scores, while eta squared was used to estimate the proportion of variance in students' critical thinking improvement explained by the treatment. According to Cohen (1988), effect size analysis is important because it provides information about the practical meaning of a treatment. This view is also supported by Becker (2020), Collins and Stevens (1983), and Sawilowsky (2009), who emphasize that statistical significance should be complemented by practical significance. Cohen's d was calculated using the following formula:

$$\text{Cohen's d} = \frac{M_1 - M_2}{Pooled\ Sd} \qquad (3)$$

and

$$S_{pooled} = \sqrt{\frac{SD_1{}^2 + SD_2{}^2}{2}} \qquad (4)$$

where d is Cohen's d, M1 is the mean pretest score, M2 is the mean posttest score, SD1 is the standard deviation of the pretest scores, SD2 is the standard deviation of the posttest scores, and SDpooled is the pooled standard deviation. The interpretation of Cohen's d is presented in Table 2.

Table 2. Cohen's d interpretation criteria

Value *d*	**Effect size category**	**Practical meaning**
$0.00 \le d < 0.20$	Very small	There is almost no difference, and it is not practically significant.
$0.20 \le d < 0.50$	Small	There is an effect, but it is not substantially significant.
$0.50 \le d < 0.80$	Moderate	The effect is meaningful and worth considering.
$0.80 \le d \le 2.00$	Large	The effect is strong and practically significant.
$D > 2.00$	Very large	The effect is very strong and highly practically significant.

In addition, the improvement in students' critical thinking skills was analyzed using the N-Gain formula to determine the effectiveness of learning improvement from pretest to posttest, as suggested by Sukarelawan et al. (2024). The N-Gain formula is presented as follows:

$$N - Gain = \frac{S_{Posttest} - S_{Pretest}}{S_{Max.} - S_{Pretest}} \quad (5)$$

where $S_{posttest}$ is the posttest score, $S_{pretest}$ is the pretest score, and S_{max} is the maximum possible score. The interpretation of N-Gain values is presented in Table 3.

Table 3. N-gain interpretation criteria

N-Gain value	**Interpretation**
$g > 0.70$	High
$0.30 \le g \le 0.70$	Moderate
$0.00 \le g < 0.30$	Low

After the N-Gain score was obtained, the results were interpreted based on the criteria in Table 3 to determine the effectiveness of the problem-solving learning model in improving students' critical thinking skills. Through this sequence of analysis, the study examined not only whether the intervention produced statistically significant improvement but also whether the improvement had meaningful practical value in the context of physics learning.

III. RESULTS

This study examined the effect of the problem-solving learning model on students' critical thinking skills in static fluid learning. The data were obtained from pretest and posttest scores administered before and after the learning model's implementation. The analysis focused on students' achievement across five indicators of critical thinking, namely elementary clarification, basic support, inference, advanced clarification, and strategy and tactics. The improvement in students' critical thinking skills was analyzed using descriptive statistics, N-Gain, a paired-samples t-test, Cohen's d, and eta-squared. The results are presented in Tables 4–6 and Figure 1.

Table 4. Average achievement of students' critical thinking skills for each indicator

No.	Critical thinking indicator	Pretest (%)	Posttest (%)	N-gain	N-gain (%)
1	Elementary clarification	41.67	84.52	0.73	73
2	Basic support	39.29	83.33	0.73	73
3	Inference	36.90	80.95	0.70	70
4	Advanced clarification	39.29	75.00	0.59	59
5	Strategy and tactics	35.71	79.76	0.69	69
	Average	**38.33**	**80.71**	**0.70**	**70**

Table 4 shows that students' critical thinking skills improved across all indicators after the implementation of the problem-solving learning model. The average pretest score was 38.33%, while the average posttest score increased to 80.71%. This result indicates a substantial improvement in students' critical-thinking performance following the intervention. The highest posttest achievement was found in the elementary clarification indicator, with a score of 84.52%, followed by basic support at 83.33%, inference at 80.95%, strategy and tactics at 79.76%, and advanced clarification at 75.00%.

The N-Gain analysis also indicates that the problem-solving learning model contributed positively to students' improvement. The elementary clarification and basic support indicators achieved the highest N-Gain values, both at 0.73 (73%). This finding suggests that students showed strong improvement in identifying problems, explaining basic concepts, and providing reasons to support their responses. The inference indicator obtained an N-Gain of 0.70, while the strategy and tactics indicator obtained an N-Gain of 0.69. Meanwhile, the advanced clarification indicator achieved the lowest N-Gain value, namely 0.59 (59%). Although this value was lower than the other indicators, it still indicates meaningful improvement after the treatment. Overall, the average N-Gain was 0.70 (70%), indicating that students' critical thinking skills improved considerably after learning through the problem-solving model.

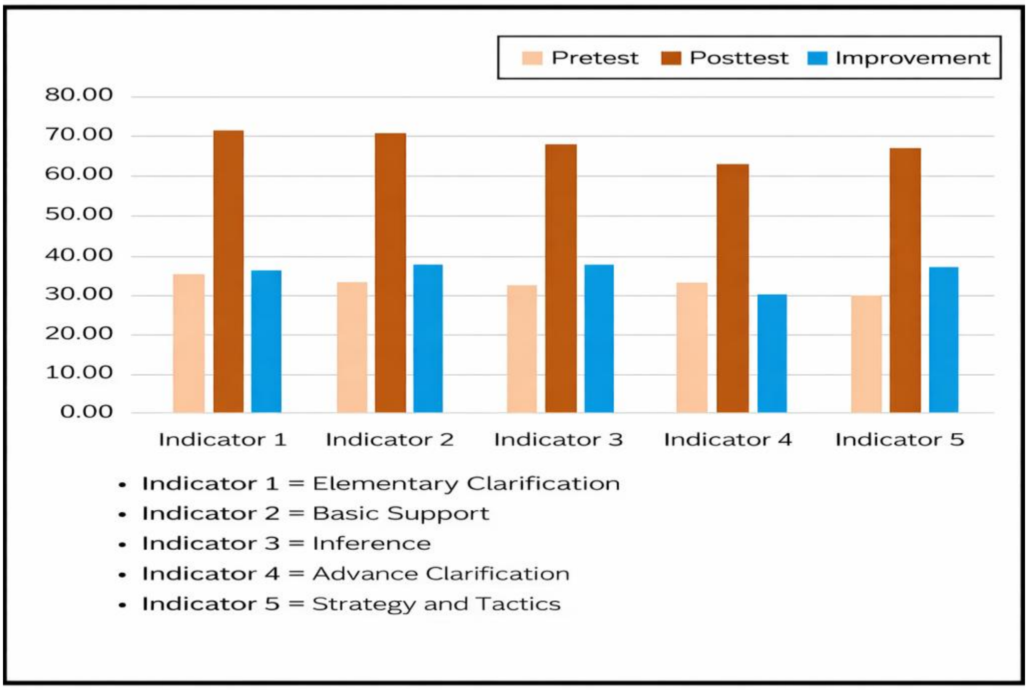

Figure 1. Improvement of students' critical thinking skills based on indicators

Figure 1 illustrates the comparison between students' pretest and posttest scores for each critical thinking indicator. The figure shows that all indicators increased after the learning intervention. This pattern confirms that the improvement was not limited to a single aspect of critical thinking but extended across all measured indicators. The largest improvements were observed in indicators related to elementary clarification and basic support, while the advanced clarification indicator showed a relatively lower increase compared with the other indicators.

To determine whether the difference between pretest and posttest scores was statistically significant, a paired-samples t-test was conducted. The result of the paired sample t-test is presented in Table 5.

Table 5. Results of the paired sample t-test

Pretest mean	**Posttest mean**	**Mean difference**	**T-value**	**P-value (two-tailed)**	**Decision**
38.33	80.71	-43.25	-25.716	0.000	H_0 rejected

Table 5 shows that the t-value was -25.716 and the p-value was 0.000. Since the p-value was lower than 0.05, the null hypothesis was rejected. This result indicates a statistically significant difference in students' critical thinking scores before and after implementing the problem-solving learning model. In other words, the use of the problem-solving learning model had a significant effect on students' critical thinking skills in static fluid learning.

Furthermore, effect size analysis was conducted to determine the practical strength of the treatment effect. The results of Cohen's d and eta squared are presented in Table 6.

Table 6. Effect size results

Effect size	Value	Category
Cohen's d	3.91	Very strong
Eta squared	0.97	Very large

Table 6 shows that the Cohen's d value was 3.91, which falls into the very strong category. This indicates that the difference between pretest and posttest scores was not only statistically significant but also practically meaningful. In addition, the eta squared value was 0.97, indicating that 97% of the variance in students' improvement in critical thinking was attributable to the implementation of the problem-solving learning model. These findings demonstrate that the problem-solving learning model had a substantial effect on improving students' critical thinking skills.

IV. DISCUSSION

The findings of this study indicate that the problem-solving learning model had a significant and meaningful effect on improving students' critical thinking skills in static fluid learning. This improvement was reflected in the increase in the average pretest score from 38.33 to 80.71 on the posttest, with an average N-Gain of 0.70 (70%), which falls into the high category. The paired-sample t-test also showed a statistically significant difference between students' pretest and posttest scores ($p = 0.000$). In addition, the effect size analysis showed a Cohen's d of 3.91 and an eta squared of 0.97, indicating that the improvement was not only statistically significant but also of strong practical significance. According to Cohen (1988), effect size analysis is important because it provides information about the practical strength of an intervention, whereas Becker (2020) and Sawilowsky (2009) emphasize that statistical significance should be interpreted alongside practical significance to understand the educational meaning of research findings. Therefore, the results of this study suggest that the problem-solving learning model provided a structured learning experience that supported students' development of critical thinking skills during physics instruction.

The improvement in students' critical thinking skills can be attributed to the characteristics of the problem-solving learning model, which requires students to actively identify problems, analyze information, formulate hypotheses, test possible solutions, and draw conclusions. These learning stages are closely related to the core processes of critical thinking, such as analysis, evaluation, inference, and decision-making. Facione (2011) explains that critical thinking involves interpreting information, analyzing arguments, evaluating evidence, and drawing reasoned conclusions. In line with this view, Jonassen (2010) states that problem-solving learning encourages students to think reflectively and systematically when dealing with complex problems. In the context of this study, students were not only asked to memorize formulas related to static fluid concepts but were also guided to understand physical phenomena through reasoning and evidence-based explanation. This learning process helped students develop a deeper conceptual understanding and strengthened their ability to analyze problems from multiple perspectives.

The greatest improvement was observed in the elementary clarification and basic support indicators, each with an N-Gain of 0.73. This indicates that students became better at identifying problems, explaining basic concepts, and providing logical reasons to support their answers. These improvements are closely related to the early phases of the problem-solving learning model, particularly problem identification and problem analysis. Through these phases, students were trained to recognize the essential elements of a physics problem, distinguish relevant and irrelevant information, and connect the problem situation with appropriate scientific concepts. Mayer (2014) argues that higher-order thinking can be developed when students are engaged in structured cognitive activities, including interpreting information, formulating explanations, and evaluating possible solutions. This finding is also consistent with Suciono (2021), who emphasizes that critical thinking in learning requires students to provide simple explanations, build basic skills, draw conclusions, provide further explanations, and develop strategies and tactics.

The inference indicator also showed a strong improvement, with an N-Gain of 0.70. This suggests that students developed a stronger ability to draw conclusions from evidence after participating in problem-based learning. In static fluid learning, students were required to interpret phenomena such as pressure, buoyancy, floating, and sinking by using relevant concepts and data. The process of testing hypotheses and comparing possible explanations enabled students to make more logical conclusions. This finding is consistent with Puspitawati and Mawardi (2022), who reported that problem-solving learning can improve students' critical thinking skills by training them to evaluate information and draw conclusions based on reasoning rather than guessing or memorization. Similarly, Septianingsih et al., (2026) found that problem-solving-based learning supports the development of higher-order thinking skills in science learning by actively engaging students in analyzing problems and constructing solutions.

The advanced clarification indicator showed the lowest N-Gain value (0.59) but still indicated meaningful improvement. This result suggests that students' ability to elaborate, justify, and evaluate arguments improved after the intervention but remained lower than other indicators. Advanced clarification requires more complex reasoning because students must not only understand the problem but also provide deeper explanations and evaluate the strength of an argument. According to Facione (2011), evaluation and explanation are advanced components of critical thinking because they require students to justify claims using relevant reasons and evidence. Therefore, although the problem-solving learning model was effective in improving this indicator, students may still need more learning time and more intensive scaffolding to strengthen their ability to construct advanced explanations.

The strategy and tactics indicator also improved from 35.71% in the pretest to 79.76% in the posttest, with an N-Gain of 0.69. This improvement indicates that students became better at selecting appropriate strategies to solve physics problems after experiencing the problem-solving learning model. In the learning process, students were encouraged to determine possible steps, test solutions, and evaluate whether their strategies were appropriate for solving static fluid problems. This is important because critical thinking in physics involves not only understanding concepts but also choosing effective procedures and justifying the reasoning behind them. Zubaidah (2016) states that critical thinking is one of the essential 21st-century skills that enables students to solve problems, make decisions, and evaluate information logically. Thus, the increase in this indicator shows that the problem-solving learning model supported students in developing more strategic and reflective approaches to learning physics.

From a theoretical perspective, the results strengthen the view that learning should involve active knowledge construction rather than passive reception of information. The problem-solving learning model aligns with constructivist learning principles because it encourages students to build understanding through experience, inquiry, and reflection. Jonassen (2010) emphasizes that meaningful problem-solving requires learners to construct mental representations of problems, explore possible solutions, and evaluate the consequences of their decisions. This perspective is also supported by Mayer (2014), who explains that meaningful learning occurs when students actively organize and integrate new information with prior knowledge. In physics learning, this process is essential because students often encounter abstract concepts that require logical reasoning and conceptual connections. Therefore, problem-solving learning can help bridge the gap between conceptual knowledge and scientific thinking.

From a practical perspective, the findings indicate that the problem-solving learning model can serve as an effective instructional alternative for physics teachers seeking to develop students' critical thinking skills. The model provides clear learning stages that help teachers guide students systematically from problem identification to conclusion drawing. In addition, the model encourages students to participate more actively in discussions, ask questions, present arguments, and reflect on their answers. These learning activities align with the demands of 21st-century education, which emphasizes critical thinking, problem-solving, collaboration, and meaningful learning (Zubaidah, 2019; Noorhapizah et al., 2022). In the context of static fluid learning, the model also enables teachers to connect abstract physics concepts to real-world phenomena, making the learning process more relevant and easier for students to understand.

However, the findings should be interpreted within the methodological scope of this study. Since the study used a one-group pretest–posttest design without a control group, the improvement in students' critical thinking skills should be understood as evidence of a strong positive change after the intervention, rather than as a comparison with other instructional models. Sugiyono (2013) explains that pre-experimental designs are useful for examining changes before and after treatment, but they have limitations in controlling external variables. Therefore, although the high N-Gain score, statistically significant t-test result, and very large effect size provide strong empirical support, future studies should consider using a more rigorous experimental design involving a control group to strengthen causal interpretation.

V. CONCLUSION AND SUGGESTION

The results of this study indicate that the problem-solving learning model significantly improves high school students' critical thinking skills in static fluid learning. This is shown by the increase in the average score from 38.33 in the pretest to 80.71 in the posttest, with an average N-Gain of 0.70, which falls into the high category. The paired-sample t-test also showed a significant difference between the pretest and posttest scores, with a p-value of 0.000 (< 0.05). In addition, the effect size analysis showed a Cohen's d of 3.91 and an eta squared of 0.97, indicating a very strong practical effect of the intervention on students' critical thinking skills. These findings confirm that the problem-solving learning model can support students in identifying problems, analyzing information, drawing conclusions, providing explanations, and developing strategies in physics learning.

This study has several limitations that should be considered. The research used a one-group pretest–posttest design without a control group, involved a relatively small sample of 24 students, and was conducted in only one school context. Therefore, the findings should be interpreted carefully and may not be fully generalizable to broader educational settings. Future research is recommended to employ a more rigorous experimental design with control groups, larger sample sizes, and more diverse school contexts. Further studies may also explore integrating digital technologies, simulations, or interactive media into problem-based physics learning. Despite these limitations, this study contributes to physics education by providing empirical evidence that the problem-solving learning model can serve as an effective instructional strategy to promote critical thinking and meaningful learning in static fluid material.

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