Analysis of Critical Thinking Ability in Physics of High School Students

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Abstract: This study describes students' critical thinking skills in static fluid learning across five public senior high schools in the West Bone region under different learning models. A quantitative descriptive survey was conducted involving 153 grade XI science students selected through purposive sampling from a population of 524 students. The research instrument consisted of 13 essay items developed from five critical thinking indicators and validated through expert review and reliability testing. Data were analyzed using descriptive statistics and category conversion. The findings show that students' critical thinking skills were generally in the good category, with the highest mean score found in the Problem-Based Learning group (29.63), followed by Project-Based Learning (27.47), Discovery Learning (26.11), Inquiry Learning (24.60), and Cooperative Learning (22.74). The results indicate that learning models emphasizing problem solving and authentic tasks tend to support higher critical thinking performance. These findings suggest the importance of selecting contextual, student-centered learning models to strengthen critical thinking in physics education.

Abstrak: Penelitian ini mendeskripsikan kemampuan berpikir kritis peserta didik pada materi fluida statis di lima SMA negeri wilayah Bone Barat berdasarkan model pembelajaran yang digunakan. Penelitian kuantitatif deskriptif ini melibatkan 153 siswa kelas XI IPA yang dipilih melalui purposive sampling dari populasi 524 siswa. Instrumen penelitian berupa 13 soal esai yang disusun berdasarkan lima indikator berpikir kritis, kemudian divalidasi oleh ahli dan diuji reliabilitasnya. Data dianalisis menggunakan statistik deskriptif dan konversi kategori. Hasil penelitian menunjukkan bahwa kemampuan berpikir kritis siswa secara umum berada pada kategori baik. Rata-rata tertinggi terdapat pada kelompok Problem Based Learning (29,63), diikuti Project Based Learning (27,47), Discovery Learning (26,11), Inquiry Learning (24,60), dan Cooperative Learning (22,74). Temuan ini menunjukkan bahwa model pembelajaran yang menekankan pemecahan masalah dan tugas autentik cenderung lebih mendukung kemampuan berpikir kritis. Dengan demikian, pemilihan model yang kontekstual dan berpusat pada peserta didik penting untuk memperkuat pembelajaran fisika. Hasil ini juga menegaskan perlunya pembelajaran aktif, kolaboratif, dan reflektif dalam kelas fisika.

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A. Introduction

Critical thinking has become one of the central competencies in contemporary education because students are expected not only to absorb information, but also to evaluate evidence, make reasoned judgments, and solve problems in complex situations. This urgency is becoming even stronger in the era of rapid artificial intelligence development and the global emphasis on education for sustainable and adaptive societies. Recent research also shows that critical thinking interventions in K–12 education have expanded substantially over the last decade, yet the field still needs more rigorous evidence from diverse contexts, especially in science-related learning areas (Walter, 2024; Wang et al., 2026).

In the Indonesian context, the need to strengthen critical thinking is particularly clear because student performance in science remains below the OECD average. In PISA 2022, Indonesian 15-year-olds scored 383 in science compared with 485 in OECD countries, and the national results declined from 2018 to 2022 in mathematics, reading, and science. At the same time, recent mapping studies indicate that most critical-thinking research in schools is concentrated in Asia, with a substantial proportion coming from Indonesia, which suggests both the importance of the topic and the need for deeper contextual studies. Local physics studies also show that students' critical thinking ability is still not optimal and varies across school settings (OECD, 2023; Marisda et al., 2024; Nurjanah et al., 2022; Wang et al., 2026).

Theoretically, critical thinking in science education is not merely a general reasoning skill, but a structured intellectual process involving interpretation, analysis, evaluation, and evidence-based judgment. Scientific thinking and critical thinking are distinct, but closely and symbiotically related; both are fundamental to science education because they help learners examine evidence and choose the most defensible explanation. For that reason, science classrooms are a natural setting for cultivating critical thinking when learning activities require students to justify answers, compare evidence, and defend conclusions logically (García-Carmona, 2025).

Physics learning is especially suitable for developing critical thinking because it requires students to connect concepts with evidence, interpret phenomena, and build logical explanations rather than memorize formulas only. Recent studies show that integrating creative pedagogy within problem-based learning can significantly improve higher-order thinking skills in science education, while guided inquiry and STEM-inquiry approaches also support students' critical reasoning. In physics classrooms, project-based learning has likewise been shown to improve critical thinking outcomes, indicating that student-centered and problem-oriented instruction can create stronger cognitive engagement (Affandy et al., 2024; Pahrudin et al., 2021; Ratu et al., 2021; Supriyatno et al., 2020).

Previous studies in the last few years consistently indicate that learner-centered instructional models are more promising for critical thinking development than passive instruction. A systematic review of problem-based learning found that most studies from 2018 to 2022 were conducted in Asia, with Indonesia contributing the largest share, and concluded that PBL is strongly associated with critical-thinking development. Similar

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findings are reported in physics-focused studies of discovery learning, which suggest that critical thinking can improve when students are actively involved in exploration and concept discovery (Anggraeni et al., 2023; Khasinah, 2021; Laeni et al., 2022; Nababan et al., 2023).

Even so, an important research gap remains. The recent K–12 scoping review shows that although the number of critical-thinking studies is large, the overall research landscape is still underdeveloped in terms of geography, grade level, and learning area, and it explicitly calls for more rigorous studies from diverse settings. In physics education, many studies still focus on a single model in a single classroom, so comparative evidence across different learning models within the same regional context is still limited. This gap matters because the effectiveness of a learning model may depend not only on the model itself, but also on teacher facilitation, student readiness, school resources, and local learning culture (Marisda et al., 2024; Nurjanah et al., 2022; Wang et al., 2026).

The novelty of the present study lies in its attempt to profile students' critical thinking skills across five public senior high schools in West Bone on the same physics topic, static fluids, while comparing five instructional models: Project-Based Learning, Problem-Based Learning, Discovery Learning, Inquiry Learning, and Cooperative Learning. Rather than testing only one intervention, this study provides a contextual comparison that may help explain how critical thinking appears under different classroom conditions. This comparative focus is important because previous studies suggest that model effectiveness is strongly shaped by implementation quality and the learning environment (Hasanah & Himami, 2021; Supriyatno et al., 2020; Walter, 2024).

Based on that background, this study asks how students' critical thinking ability is distributed across the five schools, which learning-model group shows the strongest profile, and which critical-thinking indicators require the most attention. The contribution of the study is both practical and theoretical: it provides baseline evidence for physics teachers in similar regional contexts, supports more careful selection of learning models that stimulate reasoning, and adds local empirical data to the broader international discussion on critical thinking in science education (Marisda et al., 2024; Nurjanah et al., 2022; Ratu et al., 2021).

B. Method

Building on the rationale established in the introduction, this study employed a quantitative descriptive design to describe students' critical thinking ability in static fluid learning across five public senior high schools in the West Bone region. The descriptive approach was selected because the study aimed to portray the actual condition of students' critical thinking performance within different instructional settings rather than to examine causal relationships experimentally. The population consisted of all grade XI science students from the selected schools, totaling 524 students. From this population, 153 students were selected through purposive sampling based on several criteria, namely the availability of grade XI science classes studying static fluid material and the implementation of different learning models in physics instruction. This sampling strategy was intended to ensure that

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the participants represented diverse instructional contexts while remaining aligned with the focus of the research.

The research instrument was a critical thinking essay test consisting of 13 items developed from five indicators of critical thinking, namely providing simple explanations, building basic skills, drawing conclusions, providing further explanations, and developing strategies and tactics. These indicators were adapted from the framework of critical thinking proposed by Ennis (2011), which has been widely applied in science and physics education research. Each test item was designed to measure students' ability to analyze problems, interpret scientific information, formulate logical arguments, and connect concepts to contextual situations related to static fluid phenomena. The preparation of the instrument began with constructing a test blueprint based on the alignment between critical thinking indicators and the learning objectives of static fluid material.

Before being administered to the participants, the instrument underwent a validation process to ensure the quality and appropriateness of the measurement. Content validity was evaluated by expert validators using the Gregory technique to examine the suitability of the items with the indicators and learning objectives. After the expert validation stage, empirical validity testing was conducted using Pearson Product Moment correlation analysis to determine the correlation coefficient of each item. Reliability testing was also carried out to measure the consistency of the instrument. These procedures were conducted to ensure that the instrument was capable of producing accurate and dependable data regarding students' critical thinking ability.

Data collection was conducted directly at each school through a written test administered in a single session lasting approximately 90 minutes. During the implementation, students completed the test individually under the supervision of the researchers and classroom teachers to maintain the authenticity and objectivity of the responses. The administration process was carried out simultaneously according to the schedule determined by each school. In addition to ensuring consistency in testing conditions, the supervision process also minimized the possibility of collaboration among students during the test.

The collected data were analyzed using descriptive statistical techniques. The analysis included the calculation of mean scores, standard deviation, frequency distribution, and percentage distribution of students' critical thinking achievement for each category and learning model. To facilitate interpretation, students' scores were converted into five categories of critical thinking ability: very poor, poor, fair, good, and very good. The categorization was based on predetermined score intervals adjusted to the interpretation standards of critical thinking assessment. This categorization enabled the researchers to identify the distribution pattern of students' abilities and compare the tendencies of achievement across different schools and instructional models.

The learning models implemented in the participating schools included Project-Based Learning, Problem-Based Learning, Discovery Learning, Inquiry Learning, and Cooperative Learning. Each school applied one dominant learning model in physics

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learning on static fluid material. The comparison among these instructional contexts was intended to provide a broader picture of how different classroom approaches may relate to students' critical thinking performance. Rather than positioning the models as experimentally controlled treatments, the study viewed them as naturally occurring instructional conditions found in the participating schools.

The overall procedure of the research is summarized in Figure 1. The research began with problem identification and literature review, followed by instrument development, expert validation, empirical testing, data collection, descriptive analysis, interpretation of findings, and conclusion drawing. This sequence was designed systematically to ensure that every stage of the research contributed to obtaining valid and meaningful findings regarding students' critical thinking ability in physics learning.

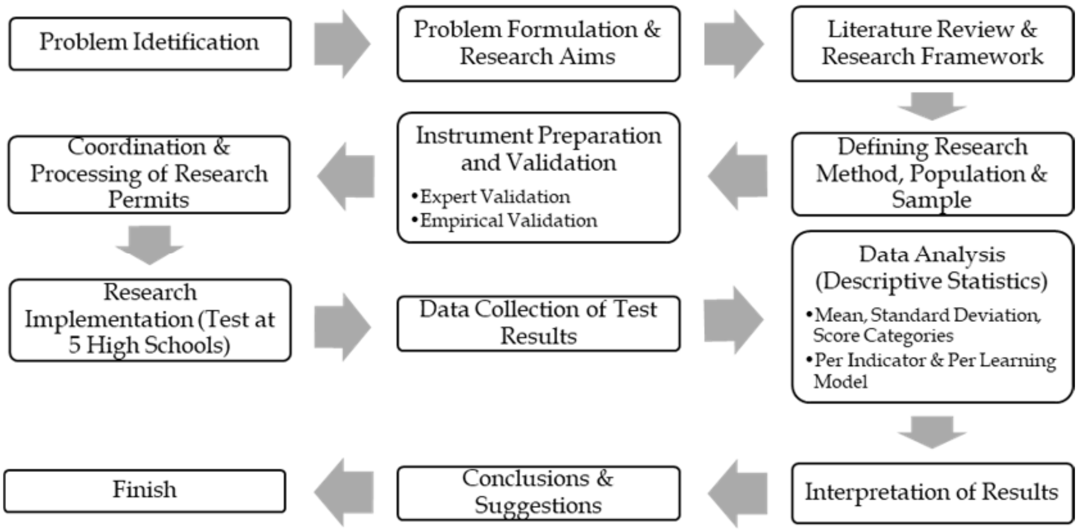

Figure 1. Research Flow

C. Result

The analysis of students' critical thinking ability in static fluid learning was conducted on 153 grade XI science students from five public senior high schools in the West Bone region. The results show that students' critical thinking skills were generally in the good category, although the distribution across categories still indicates notable variation among students. The descriptive findings are presented in Table 1.

Table 1. Descriptive Statistics of Students' Critical Thinking Ability

Statistic	Value
Number of students	153
Mean score	32.38
Mean percentage	73.74%
Highest score	38

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Statistic	Value
Lowest score	11
Standard deviation	5.42

Table 1 indicates that the average score of students' critical thinking ability was 32.38, or 73.74%, which falls in the good category. However, the relatively wide score range suggests that critical thinking achievement was not evenly distributed across all students.

Table 2. Distribution of Students' Critical Thinking Categories

Category	Score interval	Frequency	Percentage
Very poor	0–15	9	5.88%
Poor	16–20	18	11.76%
Fair	21–25	36	23.53%
Good	26–30	48	31.37%
Very good	>30	42	27.45%

As shown in Table 2, most students were distributed in the good and very good categories. In total, 90 students (58.82%) achieved scores above the fair category, while 27 students (17.64%) were still in the poor and very poor categories. This pattern indicates that although the overall ability level was relatively positive, some students still required additional support to strengthen their critical thinking performance.

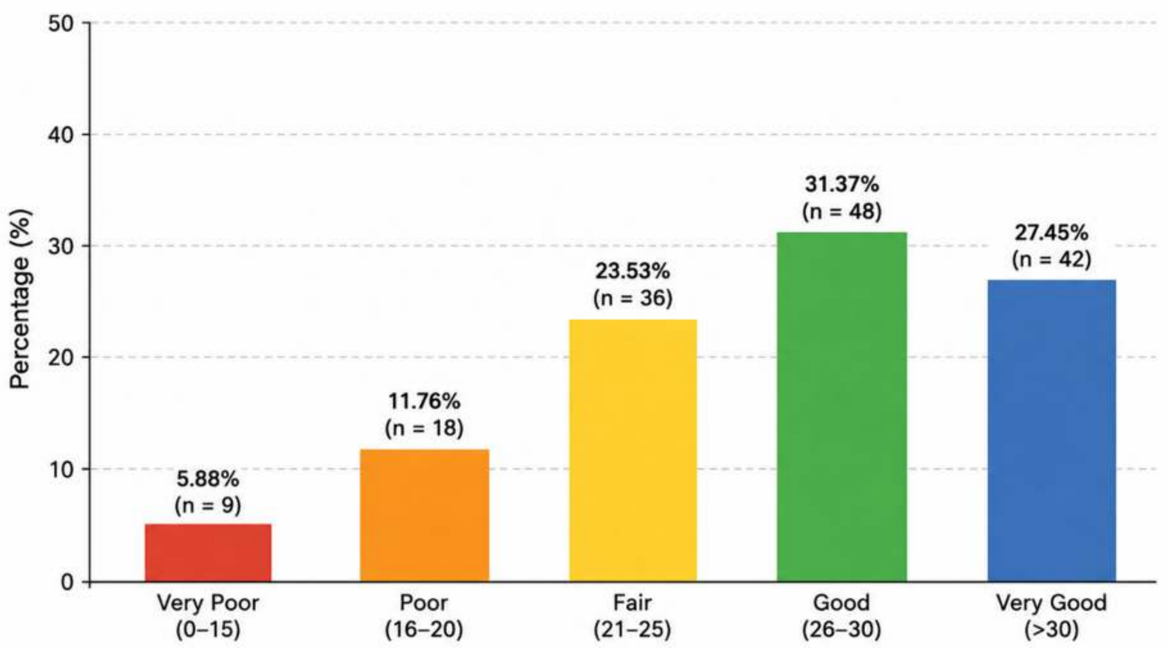

Figure 2. Distribution of Students' Critical Thinking Ability by Category

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The critical thinking performance of students was also examined based on the learning model applied in each school. The comparison shows clear differences in average achievement among schools, as presented in Table 3.

Table 3. Average Critical Thinking Score Based on Learning Model

Learning model	School	Mean score
Problem-Based Learning	SMAN 17 Bone	29.63
Project-Based Learning	SMAN 5 Bone	27.47
Discovery Learning	SMAN 20 Bone	26.11
Inquiry Learning	SMAN 22 Bone	24.60
Cooperative Learning	SMAN 25 Bone	22.74

Table 3 shows that Problem-Based Learning produced the highest mean score, followed by Project-Based Learning, Discovery Learning, Inquiry Learning, and Cooperative Learning. This result suggests that learning models emphasizing problem solving and active knowledge construction tended to support higher critical thinking performance than models centered primarily on group collaboration.

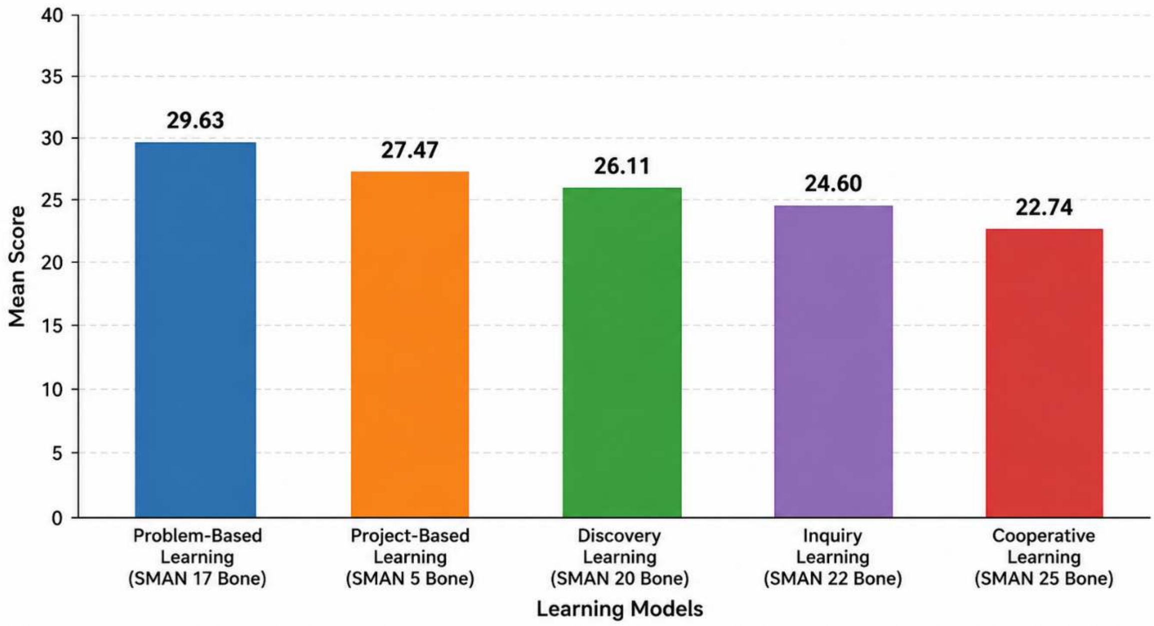

Figure 3. Comparison of Mean Critical Thinking Scores Across Learning Models

At SMAN 5 Bone, where Project-Based Learning was implemented, the distribution of students' critical thinking ability was dominated by the good and very good categories. The average score was 27.47, indicating that students in this school generally demonstrated strong critical thinking performance in static fluid learning. A smaller proportion of students remained in the lower categories, showing that improvement was still needed for some learners.

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At SMAN 17 Bone, where Problem-Based Learning was applied, students achieved the highest performance among the five schools. A total of 81.48% of students were in the very good category and 14.81% were in the good category, while only 3.70% were in the very poor category. The average score of 29.63 indicates that Problem-Based Learning was associated with the strongest critical thinking profile in this study.

At SMAN 20 Bone, where Discovery Learning was used, the category distribution was more balanced. The largest proportions of students were in the good category (31.43%) and poor category (28.57%), followed by fair (20.00%), very poor (14.29%), and very good (5.71%). The mean score of 26.11 shows that although some students performed well, the overall achievement was still moderate compared with the other schools.

At SMAN 22 Bone, where Inquiry Learning was implemented, the distribution of students' critical thinking ability was concentrated in the fair and good categories, each at 30.00%, followed by very good (20.00%), poor (13.33%), and very poor (6.67%). The average score of 24.60 suggests that Inquiry Learning supported critical thinking development, but the outcomes were not yet as strong as those obtained through Problem-Based Learning and Project-Based Learning.

At SMAN 25 Bone, which applied Cooperative Learning, the distribution of scores was relatively spread across the poor, fair, and good categories, each at 28.57%. Only 3.57% of students were in the very good category, while 10.71% were in the very poor category. The average score of 22.74 was the lowest among the five schools, indicating that Cooperative Learning in this context was less effective in promoting higher levels of critical thinking than the other instructional models.

Overall, the results reveal that students' critical thinking ability in static fluid learning was generally in the good category, but the achievement varied across schools and learning models. Learning models that placed students in problem-solving and project-oriented situations tended to produce better outcomes, while Cooperative Learning showed comparatively lower performance. These findings provide an empirical picture of how different instructional approaches relate to students' critical thinking achievement in physics learning.

D. Discussion

The findings of this study answer the first research question by showing that students' critical thinking ability in static fluid learning was generally in the good category, but the distribution was not yet fully even across learners and schools. This pattern is consistent with the wider international picture that critical thinking is now treated as a core 21st-century competence, while actual classroom development still varies widely by context and instructional design (Walter, 2024; García-Carmona, 2025). The Indonesian case is especially important because recent OECD data show that science performance remains below the OECD average, which reinforces the need for classroom environments that deliberately train reasoning and evidence-based judgment (OECD, 2023). Similar concerns appear in recent Indonesian physics studies, which report that critical thinking is still

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uneven and strongly shaped by school conditions, indicating that this competence has not yet been developed consistently across students (Marisda et al., 2024; Nurjanah et al., 2022).

The second research question is answered most clearly by the learning-model comparison: Problem-Based Learning produced the highest mean score, followed by Project-Based Learning, while Cooperative Learning produced the lowest mean score. This pattern supports the growing body of literature showing that learner-centered, problem-oriented instruction tends to strengthen critical thinking more consistently than more passive or loosely structured approaches. A systematic review by Anggraeni et al (2023) found that PBL was widely associated with gains in critical thinking, and a meta-analysis by Lu et al (2025) further confirmed that PBL is effective for improving critical thinking across studies. The same trend appears in project-based learning research: Ramadhani et al (2024) reported that PjBL can improve critical thinking in science learning, and Ratu et al (2021) also found positive effects of PjBL on students' critical thinking. In physics contexts, Pahrudin et al (2021) showed that STEM-inquiry learning can strengthen critical thinking, which supports the idea that cognitively demanding, authentic tasks are better suited for physics learning than routine exposition alone.

The middle group of results, namely Discovery Learning and Inquiry Learning, suggests that exploration-based models can support critical thinking, but only when they are implemented with strong scaffolding and clear cognitive direction. This is in line with Arifin et al (2025), whose systematic review and meta-analysis showed that inquiry-based learning has a significant effect on critical thinking in science education. Antonio & Prudente (2024) also found that inquiry-based approaches improve higher-order thinking skills, while Fitriani et al (2024) reported that guided inquiry supported by PhET media strengthens students' critical thinking in science learning. Dayu et al (2025) similarly showed that guided inquiry with digital simulations enhances critical thinking in physics. In contrast, discovery-oriented instruction does not automatically produce high outcomes unless students are guided to connect observations with explanations, a point that aligns with Nababan et al (2023), who concluded that discovery learning in physics can improve critical thinking but remains highly dependent on implementation quality. Therefore, the present study suggests that exploratory models are promising, but they need explicit scaffolding, useful learning media, and well-designed questioning to reach stronger outcomes.

The comparatively lower performance in Cooperative Learning answers the second research question from another angle: collaboration alone does not guarantee stronger critical thinking. Recent work shows that cooperative learning can improve critical thinking when tasks are structured, participation is balanced, and teacher facilitation is strong. Hayati et al (2023) reported that cooperative learning can develop students' critical thinking skills when group activities include meaningful discussion and problem solving, while Harianto (2024) found that cooperative learning positively affects critical thinking and learning outcomes when collaboration is properly organized. The present study's lower result in Cooperative Learning therefore does not mean that the model is ineffective in principle; rather, it suggests that group-based instruction without sufficiently deep individual

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cognitive engagement may leave some students passive. This interpretation is important because it shows that social interaction alone is not enough; critical thinking grows when interaction is linked to reasoning, explanation, and accountability.

The third research question is answered by the indicator-level pattern: students were stronger in providing simple explanations and building basic skills, but weaker in providing further explanations and especially developing strategies and tactics. This means that students were relatively comfortable at the level of identifying and describing ideas, but they still struggled when asked to transfer understanding into flexible solution strategies. That pattern is pedagogically meaningful because critical thinking in science is not limited to explanation; it also requires analysis, evaluation, and strategic decision-making (García-Carmona, 2025; Walter, 2024). The present findings therefore imply that physics teaching should move beyond conceptual recall toward tasks that require students to compare alternatives, justify reasoning, and design solutions. Practically, teachers in similar contexts should prioritize problem-solving tasks, authentic projects, and guided inquiry because these models have been shown to support critical thinking more consistently than conventional instruction. For future studies, a mixed-methods or experimental design would be valuable to test whether the differences observed here reflect learning-model effects, teacher facilitation differences, or broader contextual factors such as school resources and student readiness.

E. Implication

The findings of this study imply that the development of students' critical thinking skills in physics learning requires not only the implementation of student-centered instructional models, but also strong pedagogical facilitation, contextual problem design, and adequate learning support. The higher achievement observed in Problem-Based Learning and Project-Based Learning indicates that physics instruction should increasingly emphasize authentic problems, investigation, reasoning, and reflective discussion to stimulate deeper cognitive engagement. At the practical level, teachers are encouraged to design learning activities that actively involve students in analyzing evidence, constructing explanations, and evaluating solutions rather than focusing primarily on procedural problem solving. Schools and educational stakeholders may also use these findings as a reference for strengthening teacher professional development programs, improving laboratory and digital learning facilities, and promoting learning environments that support higher-order thinking skills. Theoretically, this study reinforces the growing perspective that critical thinking in science education develops more effectively through contextual, inquiry-oriented, and problem-based experiences that position students as active constructors of knowledge rather than passive recipients of information.

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F. Limitation and Suggestion for Further Research

This study has several limitations that should be considered when interpreting the findings. First, the research employed a quantitative descriptive design, so the results only provide a profile of students' critical thinking ability without examining causal relationships between learning models and critical thinking outcomes. Second, the study involved participants from only five public senior high schools in the West Bone region, which may limit the generalizability of the findings to broader educational contexts. Third, the measurement of critical thinking ability relied primarily on essay-test responses, meaning that the internal reasoning processes, classroom interactions, and learning experiences of students were not explored in depth. In addition, differences in teacher facilitation, school resources, classroom climate, and implementation quality of the learning models were not directly controlled during the research process, even though these factors may strongly influence students' critical thinking performance.

Based on these limitations, future research is recommended to employ experimental or mixed-methods approaches in order to obtain a more comprehensive understanding of how different instructional models influence students' critical thinking development in physics learning. Expanding the research area and involving more diverse school contexts would also strengthen the external validity of the findings. Further studies may integrate classroom observation, interviews, and reflective journals to capture students' reasoning processes more deeply and explain why certain learning models produce stronger critical thinking profiles than others. In addition, future researchers are encouraged to investigate the role of teacher facilitation, digital learning media, laboratory support, and students' prior academic readiness as moderating factors that may affect the effectiveness of student-centered learning models in developing critical thinking skills.

G. Conclusion

This study concludes that high school students' critical thinking ability in static fluid learning generally falls within the good category, although substantial variation remains across learning models and school contexts. Among the five instructional approaches examined, Problem-Based Learning demonstrated the strongest critical thinking profile, followed by Project-Based Learning, Discovery Learning, Inquiry Learning, and Cooperative Learning. These findings indicate that learning environments emphasizing authentic problems, investigation, reasoning, and active knowledge construction tend to support higher critical thinking performance more effectively than learning environments centered primarily on general collaboration. At the indicator level, students showed stronger performance in providing simple explanations and building basic skills, while higher-order aspects such as providing further explanations and developing strategies and tactics still require greater instructional attention.

The findings reinforce the view that critical thinking development in physics education is closely related to the quality of instructional design, teacher facilitation, and

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contextual learning experiences. Student-centered learning models can create meaningful opportunities for learners to analyze evidence, evaluate information, and construct scientific reasoning when implemented consistently and supported by adequate learning resources. Therefore, physics teachers are encouraged to design more contextual, inquiry-oriented, and problem-based learning activities that actively engage students in higher-order thinking processes. Beyond its practical contribution, this study also adds empirical evidence to the growing discussion on critical thinking development in science education, particularly within regional school contexts that remain underrepresented in current research.

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