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Profile of High School Students' Critical Thinking Skills and Problem-Solving Abilities in Static Fluid Materials

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Abstract: This study aims to describe the profile of high school students' critical thinking skills and problem-solving abilities in static fluid materials. A descriptive quantitative design was employed, involving 85 eleventh-grade students. Data were collected using essay tests based on Ennis's and Heller and Heller's indicators, then analyzed using descriptive statistics. The results revealed that students' critical thinking skills were moderate (mean: 67.01), with high proficiency in focusing on questions (97.35%) but severe weaknesses in deduction (53.24%) and induction (51.18%). Conversely, problem-solving abilities were very low (mean: 39.58), with all operational stages scoring poorly, particularly in evaluating solutions (25.65%). The study concludes that while students excel at surface-level information extraction, they experience significant cognitive bottlenecks in higher-order reasoning, physical representation, and systematic solution planning. Consequently, physics instruction must transition from procedural calculation to explicit, staged scaffolding that integrates multi-representation, scientific argumentation, and metacognitive evaluation.

Keywords: Critical Thinking; Problem Solving; Static Fluid; Physics Education; Heller Indicator

Introduction

Physics learning at the secondary level requires students not only to memorize formulas but also to interpret physical situations, connect concepts, provide scientific reasoning, and evaluate the reasonableness of their answers (Rizki et al., 2025). These demands are closely related to two higher-order thinking skills: critical thinking skills and problem-solving abilities (Demirarslan, 2026). Critical thinking focuses on the process of reflectively evaluating information and arguments, whereas problem-solving emphasizes the systematic use of concepts and strategies to achieve a solution (Liyanagamage et al., 2026). Static fluid is an ideal context for diagnosing both abilities because it combines conceptual and mathematical reasoning. In this topic, students are required to understand basic principles such as hydrostatic pressure and Archimedes' principle, while simultaneously translating verbal information into physical representations, designing solution plans, and drawing logical conclusions (Liu et al., 2026; Rath et al., 2026; Yüksel et al., 2025).

Despite this, students' higher-order thinking skills in static fluid materials still face challenges (Pantazidis et al., 2026). Students often struggle to translate problem narratives into physical representations, select relevant principles, and evaluate whether their calculation results are physically reasonable (Kimmel, 2026). Critical thinking and problem-solving skills overlap in aspects of analysis and evaluation, but they are not identical. Students may be able to identify the core of a question, but they may not necessarily be able to build a complete physical representation or design a systematic solution (Hodgkiss et al., 2025). Therefore, mapping both abilities side-by-side is necessary to provide a sharper diagnosis of students' learning obstacles (Shahini et al., 2025).

Previous studies have mostly examined these two abilities separately or focused on testing the effectiveness of specific learning models and media. This approach leaves a gap in comprehensively mapping students' initial ability profiles without treatment

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interventions. Mapping the initial profile is crucial as an empirical basis to specifically identify which aspects of ability have developed and which still need reinforcement in physics learning (Hossain et al., 2026; Kavargyris et al., 2026; Po-Sheng et al., 2026).

Based on this background, this study aims to describe the profile of high school students' critical thinking skills and problem-solving abilities in static fluid materials. Critical thinking skills are analyzed using indicators of focusing questions, analyzing arguments, deduction, and induction. Meanwhile, problem-solving abilities are analyzed based on five operational stages: focusing on the problem, describing the problem in physics concepts, planning a solution, using the solution, and evaluating the solution. The results of this study are expected to provide an empirical foundation for teachers to design physics learning that emphasizes scientific argumentation, multi-representation, and answer evaluation.

Method

Research Design

This study employed a quantitative approach with a descriptive method. This design was chosen because the research aims to map and describe students' ability profiles objectively without providing experimental treatments or comparing groups. The main focus is to diagnose the level of students' critical thinking skills and problem-solving abilities after they have learned static fluid materials.

Research Subjects

The subjects of this study were 85 eleventh-grade students from a high who had completed learning on static fluid materials. The sampling technique used was saturated sampling (*total sampling*), where all students in the target class were involved as research subjects. The determination of subjects was based on the consideration that students had completed the static fluid material, so the measured ability profile reflects the learning process that has taken place.

Research Instruments

Data were collected using two essay tests designed *based* on theoretical frameworks and adapted from previous research instruments.

Critical Thinking Skills Test: This instrument was designed based on Ennis's critical thinking indicators, which include four aspects: (1) focusing on questions, (2) analyzing arguments, (3) deduction, and (4) induction.

Table 1. Indicators of critical thinking skills used in the final analysis

Indicator	Focus of Assessment
Focusing on questions	Identifying the main question, relevant information, and necessary quantities.
Analyzing arguments	Evaluating statements, connecting concepts, and providing scientific reasons.
Deduction	Drawing logical conclusions and selecting principles or equations from available information.
Induction	Generalizing patterns or evidence and constructing conclusions based on observed cases.

Problem-Solving Ability Test: This instrument measures problem-solving abilities based on the five operational stages proposed by Heller and Heller (2010): (1) focusing on the problem, (2) describing the problem, (3) planning a solution, (4) using the solution, and (5) evaluating the solution.

Table 2. Indicators of problem-solving abilities based on Heller and Heller

Indicator	Evidence in Students' Answers
Focusing on the problem	Known/asked information, object or system, and problem target.
Describing the problem	Sketches, symbols, assumptions, and physics relationships.
Planning a solution	Selected principles, equations, and logical sequence of solutions.
Using the solution	Substitution, calculation, units, and final answer.
Evaluating the solution	Checking units, signs, magnitude of values, and physical reasonableness.

Data Collection Procedure

Both test instruments were administered to students after the entire sequence of learning on static fluid materials was completed. The tests were worked on independently within a specified time allocation. Students were instructed to write down their entire thinking process and solution steps in detail. The students' answer sheets were then collected and scored by the researcher using predetermined analytic rubrics.

Data Analysis Technique

Students' answers were assessed using analytic rubrics specifically designed for each indicator. The critical thinking rubric assesses the accuracy of the question focus, relevance of evidence, quality of arguments, and accuracy of inference. Meanwhile, the problem-solving rubric assesses the evidence of the process at each of Heller's stages. Raw scores were converted into percentage scores using the formula:

$$P = \left(\frac{\text{Obtained Score}}{\text{Maximum Score}}\right) \times 100\% \quad (1)$$

Next, the percentage scores were categorized into five scales (as presented in Table 3) to describe the level of ability achievement. The data were analyzed using descriptive statistics, including mean, standard deviation, minimum value, maximum value, median, percentage achievement per indicator, and category frequency distribution. This analysis aims to comprehensively capture the profile of students' abilities, not to draw causal conclusions or test hypotheses.

Table 3. Criteria for interpreting students' ability achievement

Score/Percentage Range	Category
85.01 – 100	Very high
75.01 – 85.00	High
65.01 – 75.00	Moderate
55.01 – 65.00	Low
0 – 55.00	Very low

Result and Discussion

Overall Descriptive Statistics

The overall descriptive statistics for students' critical thinking skills and problem-solving abilities are summarized in Table 4. The mean score for critical thinking skills was 67.01, falling into the moderate category, while the mean score for problem-solving abilities was 39.58, falling into the very low category. The standard deviation for problem-solving abilities (20.57) was notably higher than that for critical thinking skills (13.67), indicating greater variability in students' problem-solving performance.

The category distribution (Table 5) reveals that the majority of students (66 out of 85) fell into the very low category for problem-solving abilities. In contrast, critical thinking skills were more evenly distributed across categories, with the highest frequencies in the low (32 students) and moderate (29 students) categories.

Table 4. Descriptive statistics of students' abilities

Variable	Mean	SD	Min	Max	Median	Category
Critical thinking skills	67.01	13.67	25	94	69	Moderate
Problem-solving abilities	39.58	20.57	7	87	40	Very low

Table 5. Distribution of students based on ability categories

Variable	Very low	Low	Moderate	High	Very high
Critical thinking skills	9	32	29	7	8
Problem-solving abilities	66	8	7	3	1

Profile of Critical Thinking Skills

The detailed achievement of critical thinking skills based on Ennis's indicators is presented in Table 6. Students demonstrated the highest proficiency in focusing on questions, achieving 97.35% (very high category). The ability to analyze arguments was in the moderate category at 65.88%. Conversely, the indicators for deduction and induction showed the lowest proficiency, with achievements of 53.24% and 51.18%, respectively, both falling into the very low category.

Table 6. Achievement of critical thinking skills based on indicators

Indicator	Achievement (%)	Category
Focusing on questions	97.35	Very high
Analyzing arguments	65.88	Moderate
Deduction	53.24	Very low
Induction	51.18	Very low

Profile of Problem-Solving Abilities

The achievement of problem-solving abilities across the five operational stages proposed by Heller and Heller is detailed in Table 7. All five stages fell into the very low category. The highest achievement was observed in the initial stage of focusing on the problem (53.33%). Subsequent stages showed a declining trend, with describing the problem at 43.69%, planning a solution at 41.73%, using the solution at 33.89%, and the lowest achievement in evaluating the solution at 25.65%.

Table 7. Achievement of problem-solving abilities based on Heller's stages

Heller's Stage	Achievement (%)	Category
Focusing on the problem	53.33	Very low
Describing the problem	43.69	Very low
Planning a solution	41.73	Very low
Using the solution	33.89	Very low
Evaluating the solution	25.65	Very low

The findings of this study reveal a critical cognitive disconnect in how students approach static fluid problems. While students exhibit a strong capacity to extract explicit information from problem narratives, this surface-level recognition fails to translate into a coherent understanding of the physical system (Bevilacqua et al., 2026; Castelló et al., 2023; Sezgin et al., 2026). The ability to identify known and unknown variables does not inherently equip students to determine the underlying physical boundaries, select appropriate systems, or conceptualize the forces at play (Liu et al., 2026; Montuori et al., 2024; Shafer, 2025). This suggests that current instructional practices may overemphasize routine information extraction at the expense of deep physical sense-making, leaving students unprepared for the complex demands of systematic problem-solving (Dilaveroğlu, 2026; Liu et al., 2026; Vyas et al., 2026).

Furthermore, the pronounced weakness in deductive and inductive reasoning highlights a significant bottleneck in students' scientific argumentation. Students struggle to bridge the gap between recognizing a physics concept and applying it to draw logical conclusions or generalize patterns (Arıkan et al., 2024; Soler et al., 2025; Yang et al., 2025). In the context of static fluids, this manifests as an inability to reason through the interplay of variables—such as how fluid density and depth collectively dictate hydrostatic pressure—beyond merely recalling the associated formula (Chen et al., 2025; Chen et al., 2024; Vallée-Tourangeau et al., 2025). This indicates that students often view physics equations as isolated computational tools rather than expressions of physical relationships, which severely hinders their ability to construct, analyze, and evaluate scientific arguments (Çelik et al., 2025; Chen et al., 2026; Yao et al., 2026).

The systematic decline across the operational stages of problem-solving underscores that students' difficulties are not merely computational errors, but fundamental deficits in problem structuring (Çelik et al., 2025; Commodari et al., 2024; Dhanesh, 2026; Wijetunge et al., 2025). The failure to adequately describe the problem using physical representations—such as sketches, system boundaries, or force diagrams—prevents students from formulating a viable solution plan. Consequently, they bypass conceptual planning and resort to mechanical formula substitution (Eyal, 2025; Herrmann et al., 2023; Waqas et al., 2025). Most critically, the near absence of solution evaluation demonstrates a severe lack of metacognitive monitoring. Students treat the final numerical output as the absolute end of the problem-solving process, missing the crucial step of assessing whether the result is physically reasonable, dimensionally consistent, or aligned with the initial conditions of the fluid system.

The significance of these profiles lies in their direct implications for instructional design and assessment. To bridge the gap between question recognition and systematic problem resolution, physics instruction must explicitly scaffold these missing cognitive processes. Educators need to shift the instructional focus from procedural fluency to conceptual representation and metacognitive evaluation. Integrating mandatory physical representation steps—such as requiring detailed diagrams before any calculations are permitted—and embedding reflective evaluation prompts into daily assessments can force students to engage with the physical meaning of their work. Ultimately, addressing these specific cognitive bottlenecks through targeted, process-oriented scaffolding is essential for developing students' higher-order thinking and robust problem-solving capabilities in physics.

Conclusion

High school students demonstrate a moderate level of critical thinking skills but exhibit very low problem-solving abilities in static fluid materials. While students excel at surface-level information extraction, they experience significant cognitive bottlenecks in higher-order reasoning, physical representation, and systematic solution planning. Deductive and inductive reasoning remain underdeveloped, and the final stage of problem-solving—particularly evaluating the physical reasonableness of solutions—is critically neglected. Consequently, physics instruction must transition from procedural calculation to explicit, staged scaffolding that integrates multi-representation, scientific argumentation, and metacognitive evaluation to bridge the gap between merely recognizing a problem and systematically solving it.

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