

Assessing Seventh-Grade Students' Critical Thinking Skills on Temperature and Heat Using a Two-Tier Diagnostic Test

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Article Info	Abstract
Article history: Received: December 30, 2025 Accepted: March 14, 2026 Published: March 18, 2026 Keywords: Critical thinking Junior high school Temperature and heat Two-tier test This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License © 2026 Berkala ilmiah Pendidikan Fisika	Critical thinking is a fundamental competency emphasized within the Merdeka Curriculum, vital for enabling students to analyze scientific phenomena and construct reasoned explanations. This study aimed to diagnose the critical thinking skills of seventh-grade junior high school students regarding temperature and heat material using a two-tier diagnostic test. Employing a descriptive survey method, the research involved 88 students from a public junior high school in Cianjur. An instrument comprising 18 two-tier test items was developed based on Facione's critical thinking indicators: interpretation, analysis, evaluation, inference, explanation, and self-regulation. The results indicated varied competency levels across the indicators. Students demonstrated moderate performance in interpretation (53.0), analysis (51.5), and evaluation (54.5). In contrast, considerably lower scores were observed in inference (41.3), explanation (38.6), and particularly self-regulation (26.5), revealing significant challenges in drawing logical conclusions, providing coherent scientific justifications, and monitoring their own reasoning processes. These findings align with existing literature indicating that higher-order thinking skills develop gradually and require explicit instructional support. The study confirms the effectiveness of the two-tier test as a diagnostic tool for uncovering both conceptual understanding and cognitive reasoning patterns, providing an empirical profile to guide the design of differentiated, inquiry-based learning strategies in line with the formative assessment goals of the Merdeka Curriculum.
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INTRODUCTION

Critical thinking skills are one of the essential competencies mandated in the Merdeka Curriculum and are manifested in the dimensions of the Pancasila Student Profile, particularly in the element of Critical Reasoning ([Kementerian Pendidikan, 2022](#)). The implementation of learning models such as Problem-Based Learning (PBL), Project-Based Learning (PjBL), and Inquiry Learning has proven effective in developing students' critical thinking abilities ([Arifin et al., 2025](#); [Suyono et al., 2025](#); [Yu & Zin, 2023](#); [Zahra et al., 2023](#)). The models not only enhance analytical skills but also foster creativity, collaboration, and the ability to solve contextual problems, in line with the spirit of the Merdeka Curriculum ([Letluhur et al., 2025](#); [Wildan et al., 2025](#)). In the context of science learning, mastering these skills is a fundamental prerequisite for students to analyze scientific phenomena, evaluate information, and synthesize knowledge to solve real-world problems. This aligns with the vision of scientific literacy emphasized in global

assessments such as the Programme for International Student Assessment (PISA) ([Lubis et al., 2025](#); [Ramadani et al., 2025](#)).

Learning the topic of temperature and heat in Phase D (Grade VII of Junior High School/MTs) positions critical thinking skills as an essential foundation for addressing its conceptual complexity ([Chairatunnisa et al., 2023](#); [Jamaludin et al., 2022](#)). A comprehensive understanding of this topic requires strong abstraction and causal reasoning skills, while also demanding the deconstruction of common initial misconceptions among students, such as equating temperature with heat. In this context, the Merdeka Curriculum's emphasis on differentiated instruction based on levels of understanding and individual needs gains its operational relevance ([Fatimah & Muamar, 2024](#); [Mabsutsah et al., 2023](#); [Mujiburrahman et al., 2025](#)). By training students to test assumptions, analyze empirical evidence, and evaluate scientific explanations, the learning process not only aims to correct conceptual errors but also systematically builds critical reasoning skills. These skills then serve as tools for students to analyze phenomena, connect microscopic concepts with macroscopic manifestations, and solve contextual problems related to heat transfer. Thus, the integration of differentiated approaches with the strengthening of critical thinking not only addresses the internal challenges of the subject matter but also aligns with the vision of the Pancasila Student Profile and scientific literacy as the orientation of the curriculum.

In the Merdeka Curriculum, which emphasizes assessment as learning, the two-tier test serves as an effective formative approach because it not only evaluates final outcomes but also diagnoses students' reasoning processes. The first tier measures mastery of factual, conceptual, or procedural content, while the second tier explores dimensions of critical thinking such as justification, identification of assumptions, and evaluation of causal relationships ([Braun et al., 2020](#); [Wahyudi et al., 2023](#)). This structure enables researchers and teachers to capture not only whether students answer correctly, but also the reasoning patterns underlying their responses. Consequently, the two-tier diagnostic test becomes particularly relevant for analyzing critical thinking skills, as the second tier reveals students' ability to justify answers, evaluate evidence, and construct logical explanations—key indicators of critical reasoning in science learning.

Although previous studies have utilized two-tier diagnostic tests to identify misconceptions and conceptual understanding in science topics, most of these studies primarily focus on detecting students' misconceptions rather than systematically mapping critical thinking skills across multiple cognitive indicators (e.g., interpretation, analysis, evaluation, inference, explanation, and self-regulation). Moreover, limited research has examined how the two-tier diagnostic approach can be used to generate a comprehensive profile of students' critical thinking skills within the context of the Merdeka Curriculum, particularly on physics topics such as temperature and heat. Therefore, a clear diagnostic mapping of students' critical thinking skills that integrates two-tier assessment with the Critical Reasoning dimension of the Pancasila Student Profile remains relatively underexplored. At the developmental stage of Grade VII junior high school students, critical thinking skills are still in the process of formation and require appropriate scaffolding ([Azzaroiha et al., 2025](#); [Mahbubah et al., 2024](#); [Meryastiti et al., 2023](#)). Analysis of two-tier test responses can provide rich data for teachers to implement differentiated learning, which is one of the pillars of the Merdeka Curriculum. Through the combination of answer selection and reasoning justification, the two-tier format allows educators to distinguish between students who truly understand scientific concepts and those who arrive at correct answers through guessing or incomplete reasoning. This diagnostic capability makes the instrument particularly suitable for mapping students' levels of critical thinking and identifying specific misconceptions that require targeted instructional intervention. For example, students who display systematic misconceptions in the second tier (such as equating temperature with heat) may be given inquiry-based remediation activities or interactive demonstrations. Meanwhile, students who are able to

provide logical justifications can be further developed through simple projects related to the application of heat in everyday life. This approach aligns with the principle of teaching at the right level and positions assessment as an integral part of the learning process, rather than merely an end-of-course evaluation ([Evenstein Sigalov & Cohen, 2025](#); [Gleeson et al., 2025](#); [Kyriazis et al., 2025](#)).

In this regard, the present study positions itself as a baseline diagnostic study aimed at providing an empirical profile of students' critical thinking skills on the topic of temperature and heat using a two-tier diagnostic instrument. By mapping the distribution of critical thinking indicators among seventh-grade students, this study contributes not only to identifying students' conceptual and reasoning difficulties but also to providing foundational data that can support the design of differentiated instruction and inquiry-based learning strategies aligned with the Merdeka Curriculum. Theoretically, the findings are expected to strengthen the role of two-tier diagnostic assessments as tools for analyzing scientific reasoning structures, thereby extending their function beyond misconception detection toward a broader evaluation of critical thinking development in science education.

Based on this conceptual and practical alignment, the present study aims to analyze the critical thinking skill profiles of seventh-grade junior high school students within the context of the Merdeka Curriculum implementation, using a two-tier diagnostic test on the topic of temperature and heat. The analysis is expected not only to capture the level of concept mastery but, more importantly, to provide a diagnostic map that teachers can directly utilize to design differentiated learning and more effective formative assessments. The findings of this study are anticipated to contribute to strengthening Merdeka Curriculum-based teaching practices, particularly in developing learning materials, activities, and assessment instruments that specifically foster and measure the growth of critical reasoning competence within science learning at the junior high school level.

METHODS

This study employed a descriptive quantitative approach using a survey method to map and analyze the critical thinking skills of seventh-grade junior high school students in one school in Cianjur Regency, located as illustrated in Figure 1. The research was designed as a diagnostic assessment utilizing a two-tier diagnostic test instrument. This design was selected to identify not only students' conceptual mastery but also the reasoning patterns and misconceptions underlying their responses.



Figure 1 Location of the study

The population consisted of all seventh-grade students enrolled in a public junior high school in Cianjur Regency during the odd semester of the 2024/2025 academic year. In this study, cluster random sampling was applied at the class level, where each class of seventh-grade students was considered a cluster. From the available classes, several classes were randomly selected as research samples. A total of 88 students from the selected classes participated in the study. The selected classes represented heterogeneous academic

characteristics as recommended by the homeroom teachers. Since the data were collected from a single school, the findings of this study should be interpreted within the specific context of the school and are not intended for broad generalization to all junior high school students. Instead, the results provide a contextual diagnostic profile that may serve as a reference for similar educational settings.

The primary research instrument was a two-tier diagnostic test on the topic of temperature and heat, developed through several stages. In the initial design stage, items were constructed based on [Facione's \(2015\)](#) indicators of critical thinking skills—interpretation, analysis, evaluation, inference, explanation, and self-regulation—and aligned with the Phase D Learning Outcomes, resulting in a total of 18 questions. The instrument adopted a modified multiple-choice format ([Sartono et al., 2025](#); [Suwardika et al., 2024](#)), structured into two tiers. An example of the test format is presented in Table 1.

Table 1 Example of the instrument

Indicator Item	Question Form
It is interesting to compare the results of the temperature scale conversion with actual conditions.	James is Andi's friend from the United States. He explained that in New York City, the average summer temperature reaches 84.2°F. Andi was surprised, thinking that was extremely hot. James then explained that the temperature scale used in America is Fahrenheit, while in Indonesia it is Celsius.
	Tier-one Questions Based on this information, what conclusions can be made about the differences between the Fahrenheit scale and the Celsius scale? - The value on the Fahrenheit scale is always greater than on the Celsius scale for the same temperature. - Values on the Fahrenheit scale are always smaller than those on the Celsius scale. - Both scales show the same value even though they measure different objects. - The Fahrenheit scale is used to measure low temperatures, while Celsius is used for high temperatures
	Tier-two Questions Based on the first-level question, how should Andi interpret the temperature of 84.2°F mentioned by James? - Summer temperatures in New York are much hotter than in Indonesia. - Summer temperatures in New York are actually almost the same as the average temperature in Indonesia. - The Fahrenheit scale is lower than Celsius, so the numbers look smaller. - The temperature in New York cannot be compared with Indonesia because of the difference in latitude.

Expert validation was conducted to ensure the content and construct validity of the instrument. The instrument was reviewed and validated by five experts in the field of physics education. In the scoring procedure, a pair-scoring method was applied for the two-tier multiple-choice questions. A response was considered correct only when students answered both the first tier (tier-one) and the second tier (tier-two) correctly. If either the first-tier or second-tier response was incorrect, the answer was categorized as wrong ([Jusniar et al., 2020](#); [Mubarak & Yahdi, 2020](#); [Nti et al., 2023](#)). The detailed scoring method for the two-tier multiple-choice items is presented in Table 2.

Table 2 Scoring method for two-tier questions

Tier one	Tier two	Total Score
True	True	1
True	False	0
False	True	0
False	False	0

Score interpretation was carried out to evaluate students' critical thinking skills using a multiple-choice instrument supported by a scoring rubric. Each student's response was assessed according to the critical thinking indicators fulfilled. Following the administration of the instrument, the data were analyzed based on the critical thinking indicators proposed in Facione's Theory. Students were categorized as having high critical thinking skills if they achieved a score of 75 or above (Ma et al., 2021; Saphira et al., 2022), with modifications applied to accommodate the full range of values obtained from the trial results. The score ranges used in this study are presented in Table 3.

Table 3 Categories of critical thinking skills and scores

Category	Scores Range	Number of Students	Percentage (%)
Excellent	$91 \leq x \leq 100$	2	2.27
Good	$71 \leq x \leq 90$	10	11.36
Moderate	$41 \leq x \leq 70$	45	51.14
Poor	$26 \leq x \leq 40$	23	26.14
Not yet achieved	$0 < x \leq 25$	8	9.09

RESULTS AND DISCUSSION

The following are the results of the diagnostic test on critical thinking skills of junior high school students in a public school in Cianjur Regency, presented in Table 4 and Figure 1. Based on the diagnostic results using the two-tier test instrument administered to 88 students, a mapping of critical thinking skills on the topic of temperature and heat was obtained, revealing diverse characteristics. Analysis of the six critical thinking indicators proposed by Facione's theory showed significant variation in achievement, reflecting uneven development of cognitive abilities across different aspects (Gelora et al., 2022). The interpretation and evaluation indicators reached averages of 53.0 and 54.5, respectively, indicating that students tend to be able to identify problems and assess the validity of simple scientific statements. However, scores that did not reach the high category suggest that their understanding remains limited to non-complex contexts.

Table 4. Critical thinking ability test result

Skills	Q1	Q2	Q3	Average Score
Interpretation	45	56	39	53.0
Analysis	44	48	44	51.5
Evaluation	50	54	40	54.5
Inference	33	42	34	41.3
Explanation	45	24	33	38.6
Self-Regulated	20	30	20	26.5

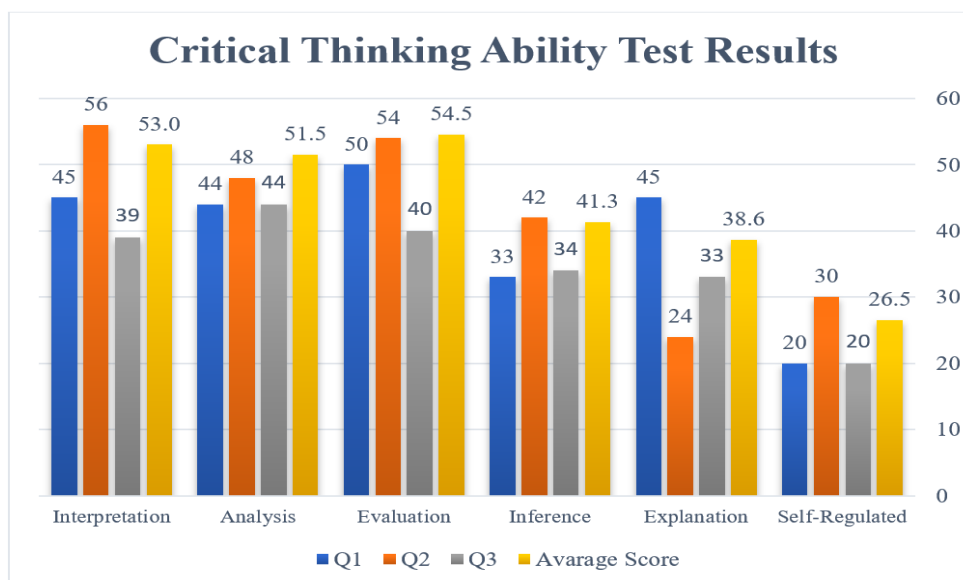


Figure 1 Critical thinking ability test result

Meanwhile, the analysis indicator averaged 51.5, confirming that students can connect information and recognize basic cause-and-effect relationships but are not yet able to conduct in-depth analysis of multi-representational phenomena such as heat transfer in everyday life. On the other hand, advanced reasoning indicators such as inference and explanation obtained lower scores, 41.3 and 38.6, respectively, signaling students' difficulties in drawing logical conclusions from data and providing coherent scientific justifications. This situation often occurs in science classrooms where learning activities still emphasize procedural problem solving and factual recall rather than encouraging students to formulate arguments based on evidence or experimental results. These findings are consistent with [Jamaludin et al., \(2022\)](#), who reported that students often succeed in answering factual questions but struggle to construct appropriate conceptual reasoning.

The sub-skill requiring the most attention is self-regulation, which achieved only 26.5, categorized as low. This reveals that students are not accustomed to engaging in critical reflection on their own thinking processes and tend not to recheck the consistency between their answers and the reasons provided. From a classroom perspective, this may indicate that opportunities for reflective learning activities, such as self-evaluation, peer discussion, or argumentation-based learning, are still limited in regular science instruction. As a result, students tend to focus on obtaining correct answers rather than examining the reasoning processes that support those answers. Such low metacognitive ability aligns with [Tukiyo et al., \(2023\)](#), who noted that the two-tier test is effective in uncovering not only misconceptions but also weaknesses in reasoning awareness.

Overall, these results indicate that although students possess a sufficient conceptual foundation, they still experience gaps in applying higher-order reasoning and critical reflection. The implication is that learning should not only strengthen conceptual understanding but also systematically train reasoning, argumentation, and self-reflection skills, for example, through guided inquiry models and evidence-based discussions. In practical classroom settings, this can be implemented through activities such as simple experiments on heat transfer, group discussions to evaluate scientific explanations, or reflective questioning that encourages students to justify their answers. These findings also highlight the relevance of using the two-tier test as a diagnostic instrument capable of providing in-depth information for designing differentiated learning, particularly on topics prone to misconceptions such as temperature and heat.

The analysis of students' critical thinking skills shows that interpretation, analysis, and evaluation indicators achieved higher scores compared to inference, explanation, and self-regulation. This finding is consistent with Facione's theory, which states that critical thinking consists of six core components that develop gradually, with higher-order aspects such as inference and self-regulation typically more difficult for students to achieve ([Plummer et al., 2022](#)). The low inference and explanation scores in this study also support [Kuhn & Modrek's \(2022\)](#) view that inference represents an advanced form of scientific reasoning because it requires the ability to logically connect evidence with claims. Furthermore, the low self-regulation score is consistent with [Karaca et al., \(2023\)](#), who emphasized that self-regulation is central to scientific thinking and often the weakest aspect among junior high school students. In the context of junior high school classrooms, these findings suggest that students still rely heavily on teacher guidance when interpreting scientific concepts and may not yet be accustomed to independently constructing scientific arguments based on evidence. In the context of using the two-tier test instrument, these findings also align with [Baah-Yanney et al., \(2025\)](#), who stated that students often provide correct answers but fail to articulate appropriate scientific reasoning, indicating misconceptions or shallow understanding. The low explanation and inference abilities are also consistent with [Valio et al., \(2025\)](#), who found that junior high school students generally remain weak in evaluating scientific arguments and constructing evidence-based justifications.

An important contribution of this study lies in the use of the two-tier diagnostic test to analyze critical thinking skills. Compared with conventional critical thinking assessments that rely solely on single-tier multiple-choice tests or written responses, the two-tier format provides deeper diagnostic information because it simultaneously measures students' answers and the reasoning behind those answers. In many traditional assessments, students may obtain correct scores through guessing or partial understanding, making it difficult to distinguish between true conceptual understanding and superficial knowledge. In contrast, the two-tier test requires students to justify their answers in the second tier, allowing researchers to identify whether correct responses are supported by valid scientific reasoning or by misconceptions. From a classroom assessment perspective, this characteristic enables teachers to better understand students' thinking processes and identify specific conceptual difficulties that may not appear in conventional multiple-choice assessments.

This dual-layer structure offers several advantages for critical thinking analysis. First, it enables the identification of reasoning patterns that correspond to specific critical thinking indicators such as inference, explanation, and evaluation. Second, it allows researchers to detect inconsistencies between students' answers and their reasoning, which is closely related to metacognitive components such as self-regulation. Third, the diagnostic nature of the two-tier instrument provides more detailed information about misconceptions and reasoning gaps compared to general critical thinking tests that only measure final answers or general reasoning ability. Such information is particularly valuable for teachers in planning targeted learning interventions, such as remediation activities for students with misconceptions or enrichment tasks for students who demonstrate stronger reasoning abilities.

Therefore, the use of the two-tier test in this study not only measures students' conceptual understanding of temperature and heat but also reveals the structure of their scientific reasoning processes. This makes the instrument particularly suitable for science education research, where understanding the relationship between conceptual knowledge and reasoning ability is essential. Compared to other critical thinking assessments, the two-tier approach offers a more comprehensive picture of students' thinking processes, enabling teachers to design more targeted learning interventions and differentiated instruction.

Taken together, this pattern of achievement shows that although students have a reasonably good initial understanding of basic concepts of temperature and heat, they still

require learning approaches that foster scientific argumentation and higher-order reasoning. In classroom practice, this implies that science learning should move beyond conceptual explanation toward activities that actively engage students in questioning, investigating, and discussing scientific evidence. This reinforces [Worachak et al., \(2023\)](#) recommendation that inquiry-based learning and scientific discussion are effective in comprehensively developing critical thinking skills, particularly in indicators that demand more complex cognitive processes.

CONCLUSION

The analysis of students' critical thinking skills using a two-tier diagnostic test on temperature and heat material shows that the development of critical thinking abilities among 7th-grade students is uneven across indicators. Interpretation, analysis, and evaluation achieved moderate scores, indicating that students are generally able to identify information, connect basic concepts, and assess simple scientific statements. However, higher-order indicators, namely inference, explanation, and especially self-regulation, were found to be significantly lower. These findings suggest that students still face difficulties in drawing logical conclusions, providing coherent scientific justifications, and monitoring their own reasoning processes.

The results are consistent with international literature stating that advanced components of critical thinking develop gradually and require explicit instructional support. The low self-regulation score highlights the need for learning designs that strengthen metacognitive awareness, while the weaknesses in inference and explanation demonstrate the importance of engaging students in evidence-based reasoning activities. The use of the two-tier test proved effective in diagnosing not only conceptual understanding but also the reasoning patterns and misconceptions that underlie students' answers.

Overall, this study emphasizes the need for learning approaches in line with the Merdeka Curriculum, particularly guided inquiry and differentiated instruction, to address diverse student needs and strengthen their critical thinking skills. The diagnostic profile obtained from this research can serve as a reference for teachers in designing formative assessments and targeted interventions that support the development of critical reasoning on temperature and heat concepts. Future research is recommended to examine the practicality and effectiveness of learning interventions tailored to the diagnostic results identified in this study.

This study has several limitations. First, the research was conducted in a single school with a limited sample size, which may restrict the generalizability of the findings. Second, the measurement of critical thinking skills relied solely on a two-tier diagnostic test, without triangulation through interviews, observations, or performance-based assessments. Third, the study focused only on the topic of temperature and heat, so the results may not represent students' critical thinking abilities across other science topics. Finally, contextual factors such as teaching strategies, classroom environment, and students' prior knowledge were not extensively controlled. Therefore, caution should be exercised when interpreting and extending these findings.

CONFLICTS OF INTEREST

The authors confirm that there are no competing interests associated with this research.

AUTHOR CONTRIBUTIONS STATEMENT

All authors contributed equally to the conception, design, data collection, analysis, and preparation of the manuscript. All authors have read and approved the final version of this article.

AI DISCLOSURE STATEMENT

The author used ChatGPT (OpenAI, version 5.2) during the preparation of this manuscript for language refinement, including improving grammar, clarity, and readability. After using this tool, the author thoroughly reviewed and edited the content as necessary and takes full responsibility for the final version of the publication.

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