

Analysis of Students' Critical Thinking Skills on Heat and Temperature Topic: A Diagnostic Study on Grade VII Junior High School Students

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Received: 20th May 2026; Accepted: 23rd June 2026; Published: 28th June 2026

DOI: <https://dx.doi.org/10.29303/jpft.v12i1.12169>

Abstract - Critical thinking is an essential competency in 21st-century science learning that supports students in analyzing information, solving problems, and making evidence-based decisions. However, the profile of junior high school students' critical thinking skills on the topic of temperature and heat has not been comprehensively mapped using indicator-level diagnostic data. This study aims to describe the critical thinking profile of seventh-grade students at SMPN 4 Mesuji Makmur on the topic of temperature and heat, based on Ennis's (2011) five critical thinking aspects and 12 indicators, using a descriptive instrument supported by qualitative interview data. A quantitative descriptive approach supported by qualitative interview data was employed. Subjects comprised 94 seventh-grade students selected through total sampling. The instrument was a 25-item multiple-choice critical thinking test based on 12 Ennis (2011) indicators (2–3 items per indicator), validated by two expert lecturers through Content Validity Ratio ($CVR \geq 0.42$), Product Moment correlation ($r > 0.361$), and Cronbach's Alpha reliability ($\alpha = 0.78$). Data were analyzed using descriptive statistics and the interactive model of Miles, Huberman, & Saldaña (2014). Results showed that the average critical thinking achievement was only 46.77% ($SD = 8.43$), in the low category (Arikunto, 2013), with 71 students (75.5%) in the low category, 18 students (19.1%) in the medium category, and 5 students (5.3%) in the high category. All five aspects were low: providing simple explanation (47.47%), building basic skills (43.94%), inferring (45.45%), providing advanced explanation (43.94%), and managing strategies and tactics (53.03%). Building basic skills and providing advanced explanation were the weakest aspects. These findings suggest the need for inquiry-based and practicum-oriented instruction specifically targeting observational reasoning and conceptual definition skills in temperature and heat learning.

Keywords: Critical Thinking; Diagnostic; Temperature and Heat; Quantitative Descriptive.

INTRODUCTION

Critical thinking skills are an essential competency that must be developed in 21st-century education, given the increasing complexity of global problems caused by the rapid development of science and technology. A report by the Organisation for Economic Co-operation and Development (OECD) emphasized that education systems need to focus on developing higher-order thinking skills so that students can analyze information, solve problems, and make rational decisions based on relevant evidence (OECD, 2019). Recent studies also show that critical thinking skills are an important predictor of academic success and

job readiness in the global era (Saavedra & Opfer, 2021; van Laar et al., 2020). PISA 2022 data also confirmed that Indonesian students' scientific literacy and reasoning skills scores remain below the OECD average, indicating the need for fundamental transformation in the learning process (OECD, 2023).

In educational studies, critical thinking skills are understood as a reflective and logical thought process to evaluate information, minimize cognitive bias, and produce accountable conclusions (Fahim & Masouleh, 2012). Ennis (2011) states that critical thinking skills encompass five main aspects: providing simple explanations

(elementary clarification), building basic skills (basic support), drawing conclusions (inference), providing further explanations (advanced clarification), and organizing strategies and tactics (strategies and tactics). These five aspects can be described into 12 measurable indicators that form the basis for developing the diagnostic instrument in this study (Ennis, 2011; Facione, 2020). A systematic review by Billah et al. (2021) found that the critical thinking skills of junior high school students in Indonesia in science learning still need to be improved across all indicators.

In Natural Science (IPA) learning, critical thinking skills play a strategic role because they require students to understand natural phenomena through scientific reasoning and empirical evidence. Science learning is not only oriented towards mastering concepts, but also towards developing scientific practices and scientific reasoning (Osborne, 2014; Bybee, 2013). One of the science topics in seventh grade that demands intensive critical thinking skills is the temperature and heat of substances. This topic is conceptual and relatively abstract because it involves understanding the relationship between temperature, heat transfer, and thermal effects on matter, while also requiring students to relate concepts to phenomena in everyday life (Doyan et al., 2023).

Various studies have shown that junior high school students' critical thinking skills in science are still relatively low. Learning tends to emphasize the use of formulas and mechanistic problem-solving without encouraging in-depth conceptual reasoning (Taufiq & Rokhman, 2017). Students also frequently experience misconceptions and difficulty linking concepts to real-world contexts (Kurniawan et al., 2022; Sari et al., 2023). Dores et al. (2020) and Utami et al. (2022) specifically reported that evaluation

and inference indicators are still low for junior high school students. Billah et al. (2021) also confirmed through a systematic review that this condition is closely related to the dominance of conventional, teacher-centered approaches, resulting in students' active involvement in higher-order thinking not developing optimally (Fitriani et al., 2021; Suradika et al., 2023).

Although research on critical thinking in science learning has been growing, most studies focus on testing the effectiveness of specific learning models and do not provide a detailed diagnostic mapping of students' critical thinking ability profiles for each indicator before the intervention is administered (Rahmawati et al., 2022; Khoiri et al., 2023; Meryastiti et al., 2022). Studies that specifically diagnose seventh-grade students' critical thinking abilities on the topic of temperature and heat using Ennis's (2011) 12 indicators comprehensively supported by qualitative data are still very limited. This gap leaves teachers without sufficient diagnostic data to design targeted learning interventions. This study aims to fill this gap by presenting a diagnostic map of seventh-grade students' critical thinking abilities as a foundation for developing more effective science learning.

The empirical conditions at SMPN 4 Mesuji Makmur reinforce the urgency of this research. Based on initial observations, the science learning process is still one-way, with the teacher's role dominating. Students are not yet accustomed to expressing opinions, analyzing problems, or drawing conclusions independently. The evaluation questions used are still in the low to medium cognitive domain, so students' critical thinking abilities have not been optimally stimulated and described. Therefore, this study aims to diagnose and describe the profile of critical thinking abilities in science of seventh-grade students at SMPN 4 Mesuji

Makmur on the topic of temperature and heat based on 12 indicators covering the five aspects of critical thinking according to Ennis (2011).

RESEARCH METHODS

This study used a quantitative descriptive approach supported by qualitative data through interviews. The quantitative descriptive approach was used to systematically describe the profile of students' critical thinking abilities based on diagnostic test scores, while the qualitative data was used to strengthen the interpretation by exploring the students' thought processes and difficulties (Creswell & Creswell, 2018).

The research was conducted at SMPN 4 Mesuji Makmur, Ogan Komering Ilir Regency, South Sumatra, during the even semester of the 2025/2026 academic year. The location was selected based on initial observations indicating low critical thinking skills in science.

The research subjects were all 94 seventh-grade students of SMPN 4 Mesuji Makmur (three study groups) using a total sampling technique (Sugiyono, 2019). For interviews, subjects were selected using purposive sampling based on the categories of high, medium, and low critical thinking abilities, each represented by three students (Moleong, 2017).

The research procedure was carried out through four stages as follows (Sugiyono, 2019; Arikunto, 2013). Stage 1 Preparation. Includes: (a) initial observation of science learning conditions; (b) proposal preparation; (c) development of multiple-choice diagnostic test instruments based on Ennis's (2011) 12 indicators on the material of temperature and heat; and (d) instrument validation by two expert lecturers. Stage 2 Implementation. Includes: (a) administering diagnostic tests to 94 seventh grade students;

and (b) conducting semi-structured interviews with 9 selected students to explore their thinking processes and difficulties experienced. Stage 3: Data Analysis. Quantitative data were analyzed using descriptive statistics; qualitative data were analyzed using the interactive model of Miles, Huberman, and Saldaña (2014). Stage 4 Reporting. The results of the analysis were synthesized and reported in the form of a scientific article accompanied by learning recommendations.

The data collection instruments consist of two types. First, a diagnostic test of critical thinking skills in the form of multiple choice consisting of 25 items arranged based on 12 indicators of critical thinking Ennis (2011) and Facione (2020), with 2–3 items per indicator, covering the following aspects: (1) providing simple explanations with sub-indicators: focusing questions (3 items), analyzing arguments (2 items), asking and answering questions (2 items); (2) building basic skills with sub-indicators: considering source credibility (2 items), observing and considering observation results (2 items); (3) concluding with sub-indicators: deduction (2 items), induction (2 items), making value judgments (2 items); (4) providing further explanations with sub-indicators: defining terms and dimensions of definitions (2 items), identifying assumptions (2 items); and (5) organizing strategies and tactics with sub-indicators: determining actions (2 items), interacting with others (2 items). Second, a semi-structured interview guide consisting of open-ended questions designed to explore students' thought processes and reasoning difficulties on the two weakest aspects: building basic skills and providing further explanations. Interviews were conducted individually in approximately 20–30 minutes per student, audio-recorded with

consent, and transcribed verbatim (Moleong, 2017; Lincoln & Guba, 1985).

Instrument validation was conducted in two stages. Content validation was conducted by two expert lecturers in science/physics education from Sriwijaya University using the Content Validity Ratio (CVR) formula from Lawshe (1975). The test items were declared content valid if the CVR value was ≥ 0.42 for the assessment by two experts (Lawshe, 1975). Empirical validation was conducted by testing the instrument on 30 students outside the research subjects. Item validity was tested using Pearson Product Moment correlation with a significance level of 5% ($r_{23} = 0.361$), while instrument reliability was tested using the Cronbach's Alpha formula. The instrument was declared reliable if the α coefficient was ≥ 0.70 (Arikunto, 2013).

Quantitative data were analyzed using descriptive statistics including the percentage of achievement per aspect and sub-indicator, overall average, maximum, minimum, and standard deviation (SD). The level of critical thinking ability was categorized into: high ($\geq 70\%$), medium (50–69%), and low ($< 50\%$), adapted from Arikunto (2013). The distribution of students across these three categories was also reported to provide a complete diagnostic picture. Qualitative data from interviews were analyzed using the interactive model of Miles, Huberman, and Saldaña (2014) through the stages of data reduction, data presentation, and conclusion drawing. Interview data were coded using an open-coding procedure aligned with Ennis's (2011) five critical thinking aspects; codes were derived inductively from transcripts and then cross-checked against the quantitative results to triangulate findings. To establish trustworthiness of the qualitative data, member checking was conducted by sharing key findings with three

interview participants to confirm accuracy of interpretation, and peer debriefing was conducted by discussing coding results with a fellow researcher (Lincoln & Guba, 1985).

RESULTS AND DISCUSSION

Results

Stage 1: Preparation for Initial Observations, Development, and Instrument Validation. In the preparation stage, initial observations were conducted by observing the science learning process in grade VII and conducting unstructured interviews with teachers. The results of the observations indicated that science learning at SMPN 4 Mesuji Makmur was still dominated by lectures and memorization assignments, with minimal activities that encouraged students to analyze, evaluate, or conclude information independently. Teachers acknowledged that the evaluation questions used were still at levels C1 to C3 of Bloom's taxonomy and therefore did not sufficiently stimulate students' critical thinking skills (Fitriani et al., 2021; Anggraeni et al., 2023).

Based on these findings, a multiple-choice diagnostic test instrument was developed that included 12 indicators of Ennis's (2011) critical thinking on the material of temperature and heat. The instrument was then validated by two expert lecturers in science/physics education. Expert assessment using the CVR formula (Lawshe, 1975) produced a CVR value ≥ 0.42 for all items, so that all items were declared valid in terms of content. Empirical trials on 30 students resulted in a Cronbach's Alpha coefficient of 0.78 (reliable category), and all items had a Product Moment correlation value above r -table (0.361), so that the instrument was declared valid and reliable (Arikunto, 2013).

Stage 2: Diagnostic Test Implementation and Interviews. In the implementation stage, the diagnostic test

was administered to all 94 seventh-grade students for 90 minutes under full supervision. After the test was completed, semi-structured interviews were conducted with nine selected students (three from each of the high, medium, and low categories). The interviews focused on exploring students' thought processes when answering questions on the most difficult aspects, particularly the aspect of building basic

skills and providing further explanations (Lincoln & Guba, 1985; Moleong, 2017).

Stage 3, Data Analysis. Critical Thinking Ability Diagnostic Test Results. The results of descriptive statistical analysis of diagnostic test data from 94 seventh grade students of SMPN 4 Mesuji Makmur are presented in Table 1 below.

Table 1. Descriptive Statistics of Critical Thinking Skills Diagnostic Test Results for Grade VII Students

No.	Descriptive Statistics	Score
1	Number of Students	94
2	Average Achievement (%) ± SD	46.77 (SD = 8.43)
3	Achievement Category	Low (< 50%)
4	Low Achievement Students (n, %)	71 (75,5%)
5	Medium Achievement Students (n, %)	18 (19.1%)
6	High Achievement Students (n, %) 5	(5.3%)
7	Highest Aspect (Strategy & Tactics Management)	53.03%
8	Lowest Aspect (Basic Skills & Advanced Explanation)	43,94%

Table 1 shows that the average achievement of critical thinking skills of 94 seventh-grade students was only 46.77% (SD = 8.43), which based on Arikunto's (2013) criteria is in the low category (<50%). The distribution of students shows that the majority, 71 students (75.5%), were in the low category, 18 students (19.1%) were in the medium category, and only 5 students (5.3%) reached the high category. This skewed distribution confirms that inadequate critical thinking

skills on the material on temperature and heat is a systemic issue, not limited to a few students. Setiawan (2023) in his research on junior high school students also found similar results, that most students were still in the low to moderate category in all aspects of critical thinking in science. Details of achievement per aspect are presented in Table 2 and Figure 1 below.

Table 2. Achievement of Students' Critical Thinking Skills per Aspect

No.	Critical Thinking Aspects	Achievements (%)	Category	Description
1	Providing Simple Explanations	47,47	Low	Below average
2	Building Basic Skills	43,94	Low	Weakest aspect
3	Concluding	45,45	Low	Below average
4	Providing Further Explanations	43,94	Low	Weakest aspect
5	Managing Strategies and Tactics	53,03	Low	Highest aspect
Overall Average		46,77	Low	

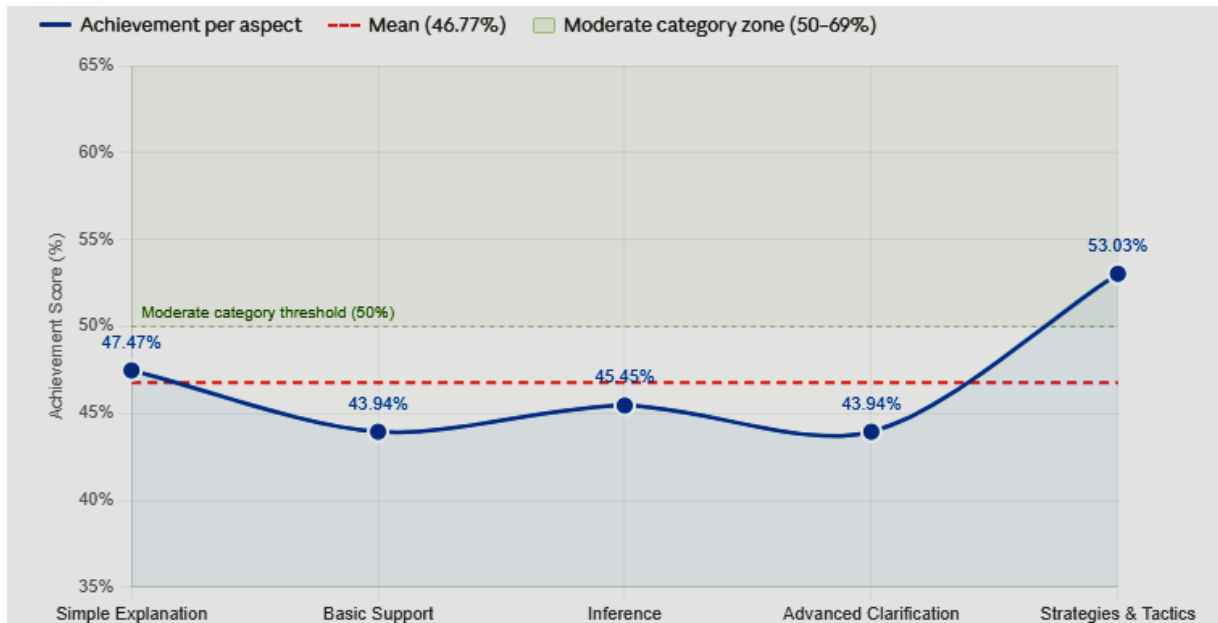


Figure 1. Achievement Line of Critical Thinking Skills of Grade VII Students of SMPN 4 Mesuji Makmur per Aspect (%)

Based on Table 2 and Figure 1, all five aspects of critical thinking skills fall into the low category. The highest score was organizing strategies and tactics (53.03%), although its score is still below the moderate category (50–69%). The lowest scores were building basic skills and providing further explanations, both of which only reached 43.94%. This indicates that students experience systematic difficulties in almost

all dimensions of critical thinking, not just specific aspects. These results align with the findings of Meryastiti et al. (2022), who identified low critical thinking skills among junior high school students across all aspects of science.

Details of achievement per sub-indicator are presented in Table 3 below, at the bottom.

Table 3. Achievement of Students' Critical Thinking Skills per Sub-Indicator

Aspect (Achievement %)	Sub-Indicators	Achievements (%)	Category
Providing Simple Explanations (47.47%)	Focusing questions	48,94	Low
	Analyzing arguments	45,74	Low
	Asking and answering questions	47,73	Low
Building Basic Skills (43.94%)	Considering the credibility of sources	44,68	Low
	Observing and considering observation results	43,19	Low
	Conclude (45.45%)	Conducting and considering deduction results	46,81
	Conducting and considering induction results	44,68	Low
	Creating and determining value judgments	44,86	Low
	Providing Further Explanation (43.94%)	Defining terms and dimensions of definitions	42,55
Determining Strategy and Tactics (53.03%)	Identifying assumptions	45,32	Low
	Determining a course of action	54,26	Low
	Interacting with others	51,81	Low
Overall Average		46,77	Low

Discussion

The overall findings of this study indicate that the critical thinking skills of seventh-grade students at SMPN 4 Mesuji Makmur on the topic of temperature and heat are in the low category, with an average achievement of 46.77% (Arikunto, 2013). This finding aligns with studies by Dores et al. (2020) and Utami et al. (2022), which found that junior high school students' critical thinking skills in science remain low, closely related to the dominance of conventional learning (Fitriani et al., 2021; Taufiq & Rokhman, 2017). Setiawan (2023) also confirmed a similar profile in eighth-grade junior high school students in East Java.

The two weakest aspects were building basic skills (43.94%) and providing further explanations (43.94%). Weaknesses in building basic skills indicate that students have difficulty carefully observing data, considering the credibility of sources, and using observations as a basis for reasoning (Ennis, 2011). This is directly related to a lack of practical experience (Osborne, 2014; Bybee, 2013; Anggraeni et al., 2023). Weaknesses in providing further explanations reflect an inability to define concepts and identify assumptions, which are high-level metacognitive skills (Facione, 2020). The aspect of concluding (45.45%) is also concerning because the ability to draw conclusions through deduction and induction is central to scientific reasoning (Ennis, 2011; Billah et al., 2021).

Interview results corroborated the quantitative findings. High-skill students were able to explain the concept of temperature and heat quite coherently, although they still had difficulty identifying assumptions. Medium-skill students tended to only be able to answer procedural questions. Low-skill students relied heavily on memorizing the formula $Q = m.c.\Delta t$

without understanding its conceptual meaning. This confirms that existing learning does not facilitate the development of critical thinking at all levels (Chairatunnisa et al., 2023). Based on this diagnostic profile, several concrete recommendations are proposed. First, implement active learning models such as inquiry-based learning or problem-based learning, which have been proven to improve junior high school students' critical thinking skills (Rahmawati et al., 2022; Suradika et al., 2023; Khoiri et al., 2023; Anggraeni et al., 2023). Second, increase contextual observation and practicum activities on temperature and heat material to strengthen the aspect of building basic skills (Osborne, 2014; Doyan et al., 2023). Third, improve the quality of evaluation questions to the HOTS (C4–C6) realm (Agus & Purnama, 2022; Facione, 2020). Fourth, provide targeted scaffolding to provide further explanations (Ennis, 2011; Billah et al., 2021).

Fifth, given that students at SMPN 4 Mesuji Makmur showed particular weakness in the aspects of building basic skills (43.94%) and providing further explanations (43.94%), STEM-integrated learning approaches are recommended for temperature and heat as well as adjacent topics in grades VII–VIII. The STEM approach requires students to engage in cross-disciplinary problem-solving, which authentically demands observational reasoning, conceptual definition, and evidence-based argumentation precisely the sub-indicators where this study found the greatest deficits (Bybee, 2013; Kurniahtunnisa et al., 2023). Doyan et al. (2023) demonstrated that STEM-based physics learning media specifically improved critical thinking in the topic of temperature and heat, while Harun & Pramasdyahsari (2023) showed that the

PjBL-STEM model effectively raised critical thinking scores in junior high school students. These approaches are particularly suited to developing the weakest indicators found in this study: observing and considering observation results, and defining terms and dimensions of definitions. science topics for grades VII-VIII, such as electricity, optics, waves, and ecosystems, where similar diagnostic profiles might be expected.

Sixth, technology integration is specifically recommended to address the two sub-indicators with the lowest scores in this study: observing and considering observation results (43.19%) and defining terms and dimensions of definitions (42.55%). PhET (Physics Education Technology) simulations provide interactive visualizations of temperature, heat transfer, and thermal phenomena that directly support the development of observational reasoning skills (Perkins, 2020; Chairatunnisa et al., 2023). Electronic interactive teaching materials in e-learning have been shown by Sinaga et al. (2022) to significantly improve critical thinking in junior high school physics. Additionally, digital platforms such as Quizizz and Kahoot! integrated with HOTS questions (C4–C6) can specifically target the inferring and strategy-and-tactics aspects—which, while not the weakest, still fall in the low category in this study (Meirbekov et al., 2022). Technology-enhanced instruction is especially valuable in the context of SMPN 4 Mesuji Makmur, where limited laboratory equipment constrains hands-on observation activities.

CONCLUSION

Critical thinking skills of seventh-grade students at SMPN 4 Mesuji Makmur on the topic of temperature and heat were uniformly low across all five aspects according to Ennis's (2011) framework, with

an overall average of 46.77% (SD = 8.43). The distribution showed that 71 students (75.5%) were in the low category, 18 students (19.1%) in the medium category, and only 5 students (5.3%) in the high category. Achievement per aspect was: providing simple explanations (47.47%), building basic skills (43.94%), concluding (45.45%), providing further explanations (43.94%), and organizing strategies and tactics (53.03%). Building basic skills and providing further explanations were the weakest aspects, with the lowest sub-indicator scores found in observing and considering observation results (43.19%) and defining terms and dimensions of definitions (42.55%), indicating that students experienced the greatest difficulties in empirical observation and conceptual definition within the topic of temperature and heat.

Based on these findings, it is recommended: (1) implementation of an active inquiry-based learning model or problem-based learning to improve critical thinking skills as a whole; (2) addition of contextual observation and practicum activities on the material of temperature and heat to specifically address the weakness in building basic skills; (3) implementation of scaffolding strategies targeting the sub-indicators of defining terms and identifying assumptions to improve the providing further explanations aspect; (4) improvement of evaluation questions to the HOTS domain (C4–C6) to better stimulate and assess higher-order thinking; (5) integration of STEM-based approaches and PhET simulations to visualize abstract thermal concepts and develop observational reasoning; and (6) use of digital learning platforms (Quizizz, Kahoot!) integrated with HOTS questions to train the inferring and strategy-and-tactics aspects. Further research is recommended to test the

effectiveness of inquiry-based and STEM-integrated interventions on the specific indicators found weakest in this study, particularly in the context of temperature and heat learning at the SMP level.

ACKNOWLEDGMENT

The author would like to thank all parties who have contributed to helping and supporting this writing and research.

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