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Analysis of Students' Profile Using Four Tier Test Instrument on Temperature, Heat, and Thermal Expansion Topics in Junior High School

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Abstract. Misconceptions are erroneous understandings of concepts that tend to persist and are difficult to change, hindering learning processes and affecting student learning outcomes. In science education, misconceptions frequently occur in highly complex concepts, particularly in temperature, heat, and thermal expansion topics. This occurs because these concepts are abstract and everyday phenomena do not always align with scientific concepts. Therefore, identifying and analyzing student misconceptions becomes crucial. This study aims to analyze students' misconception profiles on temperature, heat, and thermal expansion topics using four tier test instruments. This research employed descriptive quantitative methods with a population of all grade VII advanced students from A-accredited junior high schools in West Padang Panjang District during the second semester of 2025/2026 academic year. The sampling technique used total sampling. The research sample consisted of grade VII advanced students from three schools: SMPN 1, SMPN 2, and SMPN 4 Padang Panjang. The research instrument comprised 19 four tier test questions with four levels: concept answers, answer confidence levels, reasoning for answer selection, and reasoning confidence levels. Results showed an average percentage of students experiencing misconceptions at 24% with low category. The misconception profile revealed two indicators in moderate category: explaining temperature concepts (31.5%) and determining factors affecting heat (32%), while nine other indicators were in low category ranging from 13%-29%. Identified misconception types included false positive, false negative, and pure misconceptions.
Keywords: Misconceptions, four tier test, temperature, heat, and thermal expansion

Introduction

Education serves as a fundamental process for developing all aspects of human potential, encompassing both understanding and skills, while preparing young generations to face evolving times (Miasari et al., 2022). The implementation of educational reforms, including curriculum renewal, has become crucial to improve educational quality and produce competent graduates. One significant reform is the implementation of kurikulum merdeka, which offers diverse intracurricular learning approaches that optimize content delivery and provide sufficient time for students to deepen concepts and strengthen their competencies (Jannah et al., 2022). Science education, as one of the subjects implemented under kurikulum merdeka requirements, emphasizes direct observation of daily life phenomena and discovery processes that connect with the natural environment. This approach aligns with contemporary science education frameworks that emphasize connecting scientific concepts with everyday experiences, though such connections can sometimes lead to misconceptions when students' intuitive understanding conflicts with scientific explanations (Zoller, 2021).

Science learning requires not merely memorization but comprehensive understanding of each material. Understanding refers to an individual's ability to recognize, evaluate, develop, draw conclusions, provide illustrations, rewrite, and estimate concepts. Conceptual understanding becomes particularly important as it enables students to improve their abilities across all studied materials. However, achieving good conceptual understanding often presents challenges for students, especially in physics-related subjects, where abstract concepts can lead to misconceptions (Kurniawan et al., 2019). Research shows that students often struggle to connect formal scientific explanations with everyday experiences, contributing to persistent misconceptions (Treagust & Chandrasegaran, 2020).

Misconceptions represent erroneous interpretations of concepts that deviate from expert perspectives but tend to be maintained by students, thus impacting their achievement and approach to understanding materials (Rokhim et al., 2023). The inability of students to connect experiences with correct concepts becomes one factor causing misconceptions (Kamilah & Suwarna 2016). Deeply rooted misconceptions are difficult to correct and can negatively impact teaching and learning activities as well as students' academic achievement (Laksana, 2016). If not properly addressed, these misconceptions significantly affect students' correct knowledge and reinforce erroneous understanding (Bessas et al., 2024). These misconceptions occur due to several factors including students' prior knowledge, skills, learning resources, teaching methods used by educators, and peer interactions (Galvin et al., 2015). A study by Potvin & Cyr (2021) emphasized that addressing misconceptions requires carefully designed interventions that promote conceptual change, not just correction of wrong answers.

In science education, misconceptions frequently occur in physics concepts, particularly in temperature, heat, and thermal expansion materials. This material appears simple but possesses high complexity due to its connection with daily life phenomena that do not always align with scientific concepts (Iswanto et al., 2022). The complexity of concepts and daily experiences that are inconsistent with scientific theory cause students to often build erroneous understanding of this material. Several previous studies have proven high levels of misconceptions in temperature, heat, and thermal expansion materials. Research conducted by Yuliana et al. (2023) showed that misconceptions in temperature and heat materials reached 63.85%, categorized as moderate. Meanwhile, Sartika et al. (2021) research found misconception levels of 35.27% with the highest misconceptions found in the concept of heat's effect on thermal expansion reaching 67.74%.

To identify and analyze conceptual errors experienced by students, accurate diagnostic instruments are needed. One instrument that can be utilized is the four tier test. The four tier test adds a confidence level for the reasoning provided, making it more reliable in determining student misconceptions as it provides more comprehensive data (Triastutik et al., 2021). This instrument includes four tiers: first tier for concept answers, second tier for confidence level in answers, third tier for reasoning behind answer selection, and fourth tier for confidence in the third tier selection (Agustin et al., 2022). This method is increasingly being used internationally to detect deep-seated misconceptions with higher diagnostic accuracy compared to traditional tests (Papaphotis & Tsaparlis, 2021). The advantage of four tier test lies in its ability to examine in detail students' understanding of concepts, thus providing more valid identification of occurring misconceptions. Recent studies have validated the use of this instrument in various science topics, indicating its effectiveness in revealing the gap between knowledge and reasoning (Mufit et al., 2023).

Based on preliminary surveys with science teachers in junior high schools in West Padang Panjang District, it was found that students' misconception levels have never been evaluated using accurate examinations. According to information from three educators who served as resource persons, temperature, heat, and thermal expansion materials become among the materials that frequently experience misconceptions. This is caused by students' preconceptions that contradict expert perspectives, limited reading sources, and lack of focus in learning. This condition demonstrates the importance of conducting research to identify and analyze these misconceptions using appropriate instruments.

This research aims to describe misconceptions and calculate the percentage of grade VII junior high school students in West Padang Panjang District who experience misconceptions in temperature, heat, and thermal expansion materials using four tier test instruments.

Methods

This research employed a descriptive quantitative approach to analyze students' misconception profiles on temperature, heat, and thermal expansion topics. The study was conducted during the second semester of the 2025/2026 academic year at three A-accredited public junior high schools in West Padang Panjang District.

The research population consisted of all grade VII advanced class students from A-accredited public junior high schools in West Padang Panjang District. Total sampling technique was employed, making all population members become research samples. The sample comprised 94 students from three schools: 32 students from SMPN 1 Padang Panjang, 32 students from SMPN 2 Padang Panjang, and 30 students from SMPN 4 Padang Panjang, all from advanced classes that had completed the temperature, heat, and thermal expansion curriculum.

Data collection was conducted using four tier test instruments consisting of 19 questions covering temperature, heat, and thermal expansion concepts. Each question comprised four tiers: (1) concept answer selection, (2) confidence level regarding the chosen answer, (3) reasoning selection for the answer, and (4) confidence level regarding the selected reasoning. The instrument was adapted and modified from previous research and underwent validation by experts, reliability testing, difficulty level analysis, and discriminant power analysis before implementation.

Student conception categories were determined based on the combination of responses across all four tiers following Gurel et al. (2015) classification system as shown in Table 1. Students were categorized as having scientific conception (SC) when providing correct answers with high confidence and correct reasoning with high confidence. false positive (FP) occurred when students answered correctly with high confidence but provided incorrect reasoning with high confidence. false negative (FN) was identified when students answered incorrectly with high confidence but provided correct reasoning with high confidence. Misconception (MSC) was determined when students answered incorrectly with high confidence and provided incorrect reasoning with high confidence. All other combinations were classified as lack of knowledge (LK).

Table 1. Four tier test conception classification guidelines

Tier 1	Tier 2	Tier 3	Tier 4	Category
Correct	Confident	Correct	Confident	SC
Correct	Confident	Correct	Not Confident	LK
Correct	Not Confident	Correct	Confident	LK
Correct	Not Confident	Correct	Not Confident	LK
Correct	Confident	Incorrect	Confident	FP
Correct	Confident	Incorrect	Not Confident	LK
Correct	Not Confident	Incorrect	Confident	LK
Correct	Not Confident	Incorrect	Not Confident	LK
Incorrect	Confident	Correct	Confident	FN
Incorrect	Confident	Correct	Not Confident	LK
Incorrect	Not Confident	Correct	Confident	LK
Incorrect	Not Confident	Correct	Not Confident	LK
Incorrect	Confident	Incorrect	Confident	MSC
Incorrect	Confident	Incorrect	Not Confident	LK
Incorrect	Not Confident	Incorrect	Confident	LK
Incorrect	Not Confident	Incorrect	Not Confident	LK

(Source: Gurel et al., 2015)

Remark:
SC: Scientific conception (conceptual understanding)
FP: False positive
FN: False negative
MSC: Misconception
LK: Lack of knowledge

Data analysis involved calculating the percentage of students in each conception category for individual indicators and overall material. The misconception percentage was calculated using the following formula:

$$P = (f / N) \times 100\% \qquad (1)$$

Remark:
P = Percentage of students in each understanding category
f = Number of students in each understanding category
N = Total number of students as research subjects

Based on Triana (2023), misconception categories were determined using established criteria where false positive and false negative conditions indicate occurrence of misconceptions, resulting in three misconception categories: false positive, false negative, and pure misconceptions. False positive occurs when students provide correct answers in tier one but incorrect reasoning in tier three while showing high confidence in both tiers two and four. False negative emerges when students provide incorrect answers in tier one but correct reasoning in tier three with high confidence in tiers two and four. Pure misconception occurs when students provide incorrect answers in both tier one and three while maintaining high confidence in tiers two and four.

The misconception levels were categorized based on percentage ranges: low (0-30%), moderate (31-60%), and high (61-100%) following Maison et al. (2021) classification system. This categorization enables systematic interpretation of misconception severity across different indicators and provides meaningful benchmarks for educational intervention planning. Statistical analysis was performed using descriptive statistics to determine frequency distributions and percentages for each conception category across different indicators and schools.

Results and Discussion

Based on students' responses to each test item, students were classified into five categories: scientific conception, misconception, false positive misconception, false negative misconception, and lack of knowledge. Students' understanding levels for each indicator are presented in Table 2.

Table 2. Students' understanding level for each indicator test item

Indicators	Item Number	SC (%)	MSC (%)	LK (%)
1. Explaining temperature concepts	1	19	44	37
	2	52	19	29
2. Explaining temperature phenomena in daily life	3	31	29	40
	4	55	19	26
3. Applying temperature scale measurements with various scales	5	20	25	55
4. Describing heat concepts	6	26	18	56
	7	56.4	7.4	36.2
5. Describing the relationship between heat and temperature change	8	12	20	68
6. Determining types of heat transfer	9	48	29	23
7. Differentiating heat transfer through conduction, convection, and radiation	10	10	21	69
	11	35	13	52
	12	43	16	41
8. Explaining heat phenomena in daily life	13	30	15	55
	14	10.6	25.5	63.9
	15	13	20	67
9. Determining factors affecting heat	16	21	32	47
10. Explaining coefficients of linear, area, and volume expansion	17	22	28	50
11. Explaining expansion properties caused by temperature, heat, and thermal expansion	18	8.5	28.7	62.8
	19	35	13	52

Table 2 shows three categories of students' conceptual understanding levels. The scientific conception (SC) category achieved its highest percentage of 48% in indicator 6 (determining types of heat transfer). The misconception category reached its peak at 32% in indicator 9 (determining factors affecting heat). The lack of knowledge (LK) category demonstrated its highest percentage of 68% in indicator 5 (describing the relationship between heat and temperature change). Figure 1 presents students' overall understanding levels on temperature, heat, and thermal expansion topics.

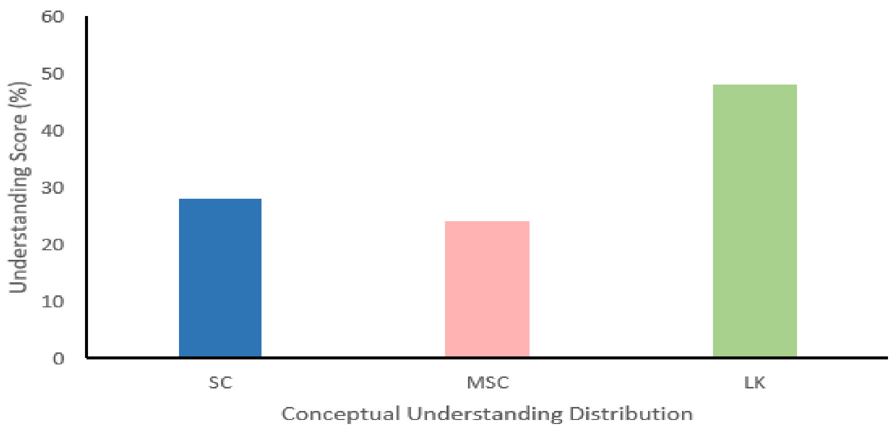

Figure 1. Average conceptual understanding level of grade VII students in West Padang Panjang District on temperature, heat and thermal expansion topics

Students' misconception levels were categorized into three types: pure misconceptions, false positive misconceptions, and false negative misconceptions, following Triana's (2023) framework where false positive and false negative conditions indicate misconception occurrence. Table 3 presents the misconception levels experienced by students for each indicator.

Table 3. Students' misconception level for each indicator test item

Indicators	Item Number	MSC (%)	FP (%)	FN (%)
1. Explaining temperature concepts	1	30	1	13
	2	13	2	4
2. Explaining temperature phenomena in daily life	3	22	5	1
	4	10	6	3
3. Applying temperature scale measurements with various scales	5	11	9	5
4. Describing heat concepts	6	12	2	4
	7	2	2	3
5. Describing the relationship between heat and temperature change	8	19	0	1
6. Determining types of heat transfer	9	3	25	1
7. Differentiating heat transfer through conduction, convection, and radiation	10	11	4	6
	11	5	2	5
	12	14	0	2
8. Explaining heat phenomena in daily life	13	9	3	3
	14	10	15	1
	15	13	3	4

Indicators	Item Number	MSC (%)	FP (%)	FN (%)
9. Determining factors affecting heat	16	4	25	3
10. Explaining coefficients of linear, area, and volume expansion	17	23	3	2
11. Explaining expansion properties caused by temperature, heat, and thermal expansion	18	16	4	9
	19	6	1	5

Table 3 reveals that students' average misconception levels were distributed as follows: 12% for pure misconceptions, 8% for false positive misconceptions, and 4% for false negative misconceptions. Figure 2 illustrates students' overall misconception levels on temperature, heat, and thermal expansion topics.

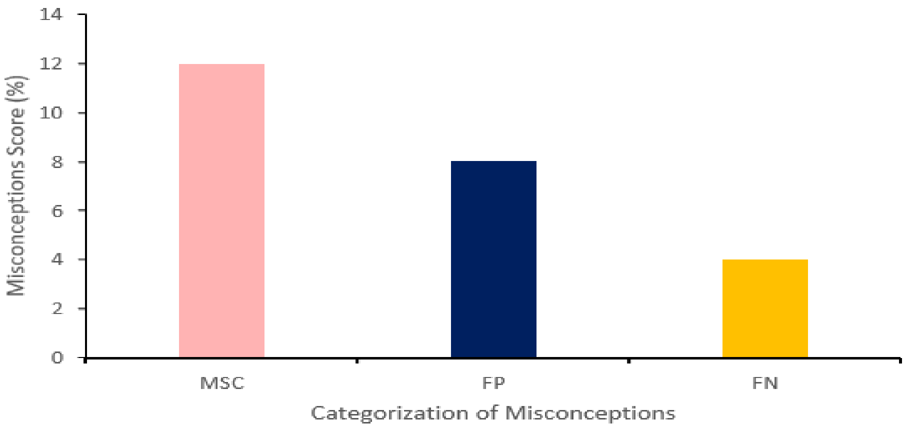

Figure 2. Average misconception level of grade VII students in West Padang Panjang District on temperature, heat and thermal expansion topics

Furthermore, to facilitate targeted remediation strategies, student misconceptions were categorized according to their severity levels, as presented in Table 4.

Table 4. Categories of student misconceptions on temperature and heat concepts

Indicators	Misconception Rate (%)	Category Level
1. Explaining temperature concepts	31.5	Moderate
2. Explaining temperature phenomena in daily life	24	Low
3. Applying temperature scale measurements with various scales	25	Low
4. Describing heat concepts	13	Low
5. Describing the relationship between heat and temperature change	20	Low
6. Determining types of heat transfer	29	Low
7. Differentiating heat transfer through conduction, convection, and radiation	17	Low

Indicators	Misconception Rate (%)	Category Level
8. Explaining heat phenomena in daily life	20	Low
9. Determining factors affecting heat	32	Moderate
10. Explaining coefficients of linear, area, and volume expansion	28	Low
11. Explaining expansion properties caused by temperature, heat, and thermal expansion	21	Low

The detailed analysis of misconceptions provides crucial insights for instructional design and remediation strategies. Each identified misconception represents a systematic error in students' conceptual frameworks that requires targeted intervention.

Indicator 1: Explaining Temperature Concepts

The second highest misconception occurred in the indicator of explaining temperature concepts with a percentage of 31.5%. This finding indicates that students experience significant difficulties in understanding the nature of temperature as an intensive quantity. The main misconception identified is the assumption that water at 40°C feels "twice as cool" compared to water at 80°C. Students tend to treat temperature as an extensive quantity that can be compared proportionally. This conceptual error aligns with the findings of Kiswanto (2022), who stated that temperature is an intensive quantity that indicates the average kinetic energy level of particles and cannot be compared using simple mathematical terminology such as "twice as cool." The correct concept is that temperature indicates the intensity of heat in an object, not the quantity of heat it contains.

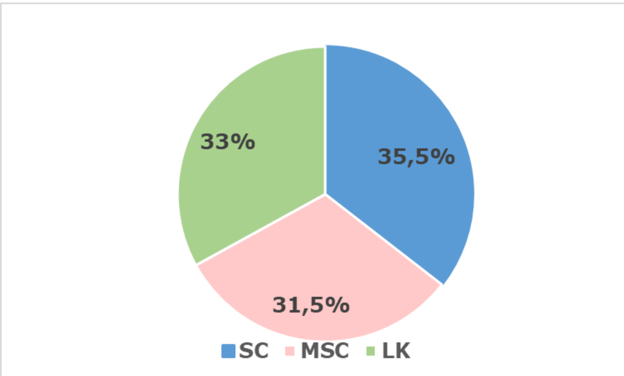

Figure 3. Misconceptions in temperature concept

Indicator 2: Explaining Temperature Phenomena in Daily Life

In this indicator, 24% of students experienced misconceptions related to temperature phenomena in applicative contexts. The dominant misconception is the assumption that iron has a lower temperature than wood when both are in the same room. This conception ignores the fundamental principle of the zeroth law of thermodynamics, which states that objects in thermal equilibrium with the same environment will have identical temperatures (Nuriyah, 2021). The difference in sensation felt when touching iron and wood is not caused by temperature differences, but rather by the difference in thermal conductivity of both materials. Iron, as a good conductor, quickly transfers heat from the hand, creating a cold sensation. Conversely, wood as a relatively poor insulator does not easily transfer heat, so it feels warmer despite having the same temperature as iron.

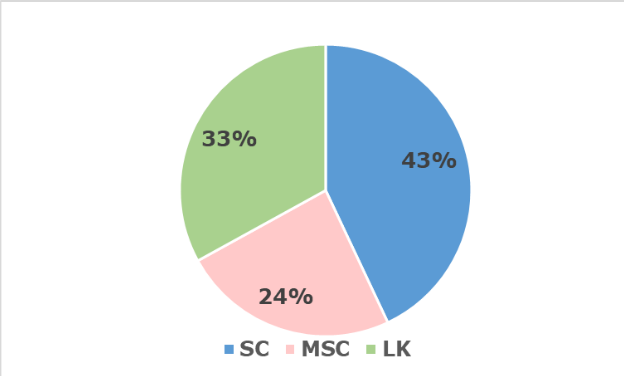

Figure 4. Misconceptions in temperature phenomena

Indicator 3: Applying Temperature Scale Measurements with Various Scales

A total of 25% of students showed misconceptions in the aspect of temperature measurement using various scales. The main misconception is the assumption that if two thermometers show different results when measuring the same object, then one of the thermometers must be damaged. This conception shows a lack of understanding that temperature can be expressed in various measurement scales that have different references. Prihandono (2021) emphasized that temperature is a relative quantity whose value depends on the measurement scale used. Celsius, Fahrenheit, Reamur, and Kelvin thermometers have different reference points and intervals, so the numerical values produced will differ even when measuring the same temperature. What is important is consistency in scale usage and accuracy in inter-scale conversion, not numerical value similarity.

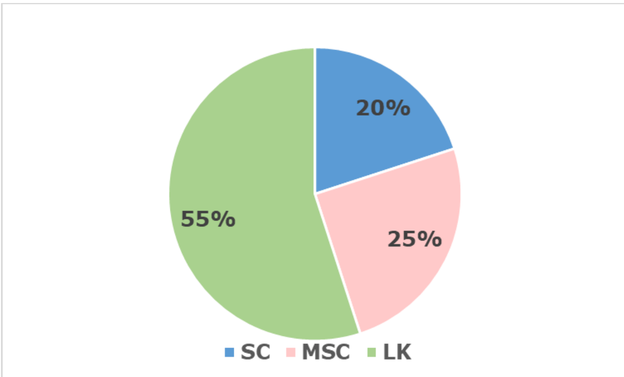

Figure 5. Misconceptions in temperature scale measurement

Indicator 4: Describing Heat Concepts

This indicator shows the lowest level of misconception with a percentage of 13%. Although relatively low, the misconceptions that occur are quite fundamental, namely misunderstanding of the direction of heat flow. Some students assume that heat flows from ice to the environment on the grounds that ice "releases cold" to its surroundings. This conception contradicts the Second Law of Thermodynamics, which clearly states that heat always flows from objects at high temperature to objects at low temperature spontaneously, and never flows in the opposite direction without external work assistance (Zakaria et al., 2024). In the context of ice melting at room temperature, heat flows from the environmental air (higher temperature) to ice (lower temperature), which is then used for the phase change process from solid to liquid.

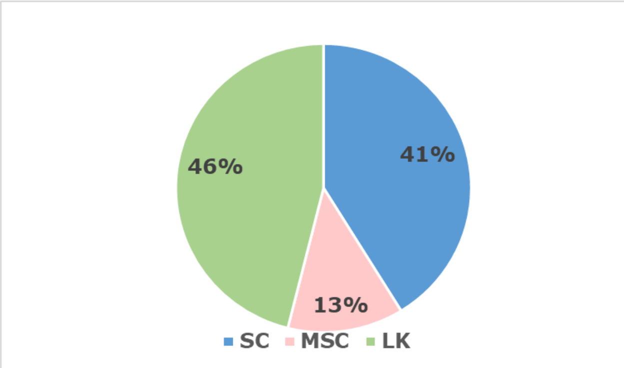

Figure 6. Misconceptions in heat concept

Indicator 5: Describing the Relationship between Heat and Temperature Changes

A total of 20% of students experienced misconceptions about the relationship between heat and temperature change. The main error is the assumption that substances with large specific heat will experience higher temperature increases when receiving the same amount of heat. This conception is the opposite of the actual relationship explained in the equation $Q = m.c.\Delta T$. Taqwa et al. (2019) explained that from this equation it can be derived that $\Delta T = Q/(m.c)$, which shows an inversely proportional relationship between temperature change (ΔT) and specific heat (c). This means that for the same mass and heat, substances with smaller specific heat will experience greater temperature increases. For example, cooking oil, which has a smaller specific heat compared to water, will experience a higher temperature increase when both are heated with the same heat.

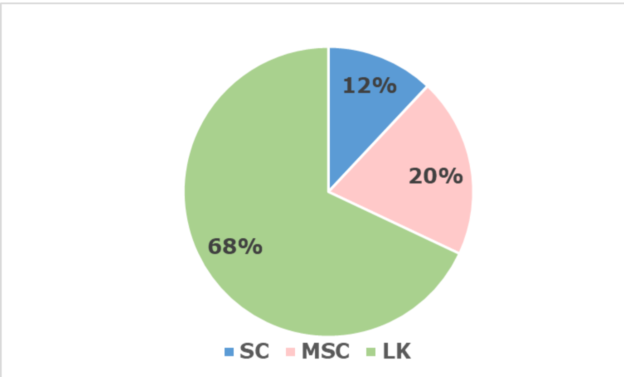

Figure 7. Misconceptions in heat-temperature relationship

Indicator 6: Determining Types of Heat Transfer

This indicator shows a misconception of 29%, which is the third highest in this study. The dominant misconception is the misunderstanding about the type of heat transfer from a campfire to the human body. Many students assume that this transfer occurs through conduction and requires an intermediary medium. The correct understanding is that heat transfer from a campfire to the body occurs through radiation, namely heat transfer without requiring an intermediary medium through electromagnetic waves. He et al (2024) explained that the warm sensation felt by the body when near a campfire is the result of thermal radiation emitted directly by the heat source to its surrounding environment. This phenomenon can occur even in a vacuum, which proves that no intermediary medium is required for the heat transfer process through radiation.

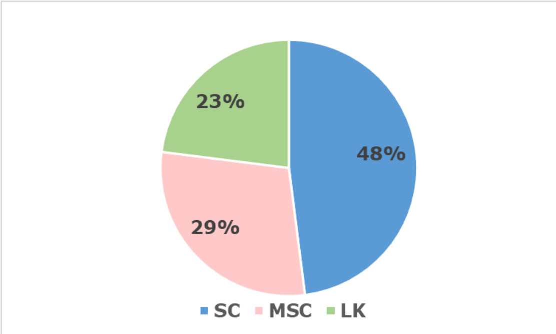

Figure 8. Misconceptions in identifying heat transfer types

Indicator 7: Differentiating Heat Transfer through Conduction, Convection, and Radiation

A total of 17% of students experienced misconceptions in differentiating the three types of heat transfer. The main error occurred in identifying the type of heat transfer when cooking water, where students considered this process to occur through conduction. Menurut Kusrini et al. (2023) heat movement through liquids or gases is called convection, so the water cooking process involves convection processes. In the water heating process, water at the bottom will be heated first, experience expansion so its density decreases, then rise upward and be replaced by cold water from the top that falls downward. This movement of water mass (fluid) that carries heat energy is called convection. Conversely, conduction occurs through vibration and collision between particles without mass transfer of material, as occurs in heating metal rods.

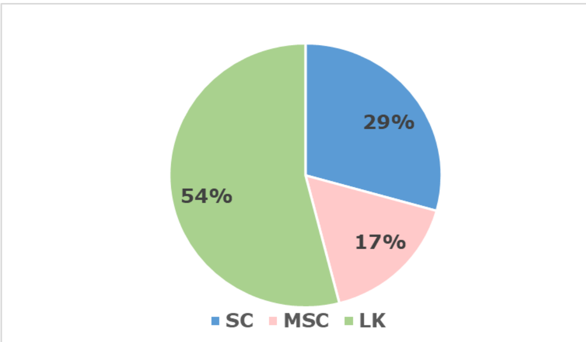

Figure 9. Misconceptions in differentiating heat transfer mechanisms

Indicator 8: Explaining Heat Phenomena in Daily Life

In this indicator, 20% of students showed misconceptions related to the application of heat concepts in real contexts. One significant misconception is the assumption that shiny surfaces absorb heat well. This conception contradicts the actual physical properties of shiny surfaces. Sari et al. (2023) explained that shiny surfaces are poor absorbers and simultaneously poor emitters of thermal radiation. This property enables shiny surfaces to retain heat effectively, as applied to the silver layer in thermos bottles. Shiny surfaces can prevent radiation from leaving the system, thus maintaining internal temperature longer.

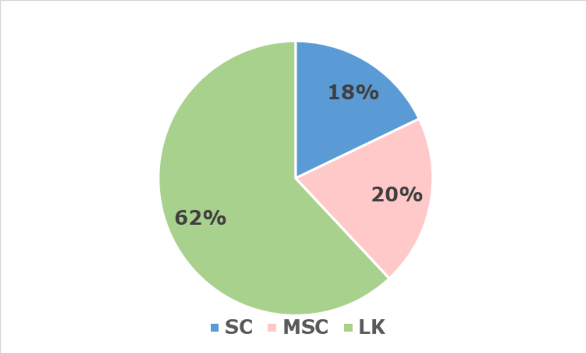

Figure 10. Misconceptions in heat phenomena

Indicator 9: Determining Factors Affecting Heat

This indicator shows the highest level of misconception with a percentage of 32%. The main misconception is the assumption that latent heat is one of the factors affecting heat capacity. This error shows students' lack of understanding of the concept of heat capacity and the factors that influence it. Based on the equation $Q = m.c.\Delta T$, heat capacity (C) can be derived as $C = Q/\Delta T = m.c$. From this equation, it is clear that the factors affecting heat capacity are only mass (m) and specific heat (c), not latent heat. Latent heat relates to phase changes at constant temperature, while heat capacity relates to an object's ability to absorb heat to undergo temperature changes.

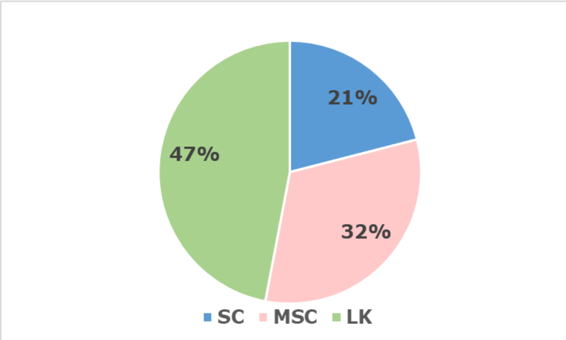

Figure 11. Misconceptions in factors affecting heat

Indicator 10: Explaining Linear, Area, and Volume Expansion Coefficients

A total of 28% of students experienced misconceptions about thermal expansion concepts. The dominant misconception is the assumption that when an iron ring is heated, its inner diameter will shrink because the metal expands "inward." The correct concept is that when heated, the ring will experience expansion in all directions, including outward from the hole so that the inner diameter actually increases. In accordance with the principle of expansion, the size of an object caused by temperature increase will make all dimensions of the object larger (Kapul et al., 2023). This phenomenon occurs because increased particle kinetic energy causes inter-atomic distances to increase, so the overall dimensions of the object increase.

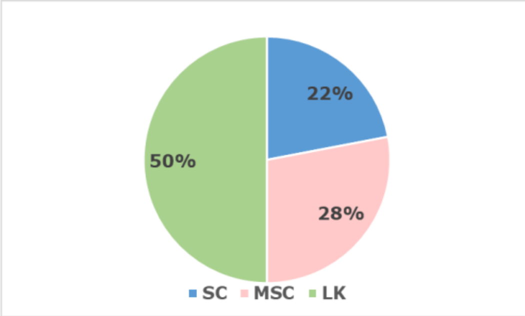

Figure 12. Misconceptions in thermal expansion coefficients

Indicator 11: Explaining Expansion Properties Caused by Temperature, Heat, and Expansion

The final indicator shows a misconception of 21% among students. The main misconception occurs in comparing expansion between solid balls and hollow balls when heated. Students assume that the volume of hollow balls will be larger than solid balls after heating.

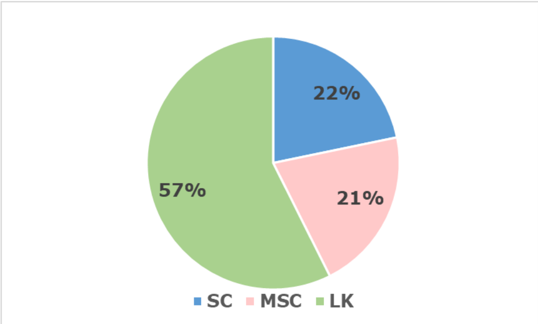

Figure 13. Misconceptions in thermal expansion properties

The correct understanding is that solid balls and hollow balls with the same material and initial dimensions will experience identical volume expansion when heated to the same temperature (Ariska et al., 2024). This is because thermal expansion depends on the volumetric expansion coefficient of the material ($\beta = 3\alpha$) and temperature change, not on mass distribution or internal structure of the object. Both balls experience identical expansion because the expansion coefficient is an intrinsic property of the material.

Conclusion

Students' misconceptions on temperature, heat, and thermal expansion topics in junior high school were successfully identified using the four tier test instrument. The overall misconception rate across all indicators reached twenty-four percent, which falls into the low category. Two indicators showed moderate level misconceptions, specifically explaining temperature concepts and determining factors affecting heat. The remaining nine indicators demonstrated low level misconceptions. Three types of misconceptions were found during the study, including false positive, false negative, and pure misconceptions. The four tier test instrument effectively identified and categorized student misconceptions by incorporating confidence levels in both answers and reasoning processes.

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