

Investigating Senior High School Students' Conceptual Understanding of Heat and Temperature: A Qualitative Analysis in Physics Education

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Abstrak

Perbedaan antara panas dan suhu merupakan konsep yang mendasar dalam pembelajaran fisika, namun masih menjadi sumber miskonsepsi yang terus-menerus muncul di kalangan siswa. Miskonsepsi dapat menghambat perkembangan pemahaman konseptual dalam topik termodinamika dan perpindahan energi. Penelitian ini bertujuan untuk menyelidiki pemahaman konseptual siswa SMA terhadap konsep panas dan suhu melalui pendekatan kualitatif. Partisipan penelitian terdiri atas 30 siswa kelas XI dari salah satu SMA negeri di Indonesia. Data dikumpulkan melalui delapan butir tes diagnostik terbuka dan wawancara semi-terstruktur yang menggali penalaran siswa mengenai fenomena termal sehari-hari. Analisis tematik mengungkap empat pola miskonsepsi utama, yaitu: (1) panas sebagai zat, di mana panas dianggap sebagai energi material yang dapat mengalir; (2) penyamaan panas dan suhu, ketika suhu diperlakukan sebagai total panas; (3) perpindahan dingin, yaitu keyakinan bahwa “dingin” itu sendiri berpindah antar benda; dan (4) kebingungan hubungannya antara ukuran benda dan suhu, yaitu anggapan bahwa benda berukuran lebih besar selalu memiliki suhu yang lebih tinggi. Studi ini menegaskan pentingnya pendekatan kualitatif dalam mengungkap cara berpikir siswa, bukan sekadar frekuensi kesalahan. Implikasi pembelajaran meliputi penggunaan visualisasi pada tingkat partikel, kegiatan memprediksi–mengamati–menjelaskan, serta eksperimen kontras untuk membantu siswa membangun kembali model ilmiah yang akurat tentang panas dan suhu.

Kata Kunci: Panas, Suhu, Miskonsepsi, Studi Kualitatif, Pendidikan Fisika.

Abstract

The distinction between heat and temperature is fundamental in physics learning, yet it remains a persistent source of student misconceptions. Such misunderstandings hinder conceptual development in thermodynamics and energy transfer. This study investigated senior high school students' conceptual understanding of heat and temperature through a qualitative approach. Participants were 30 Grade XI students from a public high school in Indonesia. Data were collected using an eight-item diagnostic test and semi-structured interviews exploring students' reasoning about thermal phenomena. Thematic analysis revealed four dominant patterns: (1) heat as a substance, where heat was viewed as material energy; (2) heat–temperature equivalence, where temperature was treated as total heat; (3) cold transfer, the belief that coldness itself moves between objects; and (4) size–temperature confusion, assuming larger objects always have higher temperature. The study underscores the importance of qualitative inquiry in revealing students'

reasoning, not just frequencies. Instructional implications include particle-level visualization, predict–observe–explain activities, and contrastive experiments to help students reconstruct accurate models of heat and temperature.

Keywords: Heat, Temperature, Misconceptions, Qualitative Study, Physics Education.

INTRODUCTION

Physics education today emphasizes not only the mastery of problem-solving procedures but also the development of coherent conceptual understanding of natural phenomena. Among the fundamental topics in secondary physics, the concepts of heat and temperature are critical because they underpin thermodynamics, energy transfer, and kinetic theory. However, recent studies continue to show that students struggle to differentiate between these two concepts, leading to persistent misconceptions that hinder meaningful learning (Muñoz Contel et al., 2017; Métioui, 2023; Siahaan et al., 2021; Pratama & Suhandi, 2023; Yulianti et al., 2022). Similar findings have also been reported in Southeast Asian contexts (Halim, Yusof, & Meerah, 2020), indicating that such difficulties are not limited to a single cultural or curricular setting.

A major difficulty lies in the widespread substance-based model of heat, in which students perceive heat as a tangible entity that can be stored or transferred rather than as energy in transit. This misconception remains prevalent even after conceptual-change-oriented instruction, as learners continue to interpret thermal interactions through intuitive analogies such as “heat moves like a fluid” (Muñoz Contel et al., 2017; Métioui, 2023). Similarly, temperature is often equated with the total amount of heat contained in an object, producing the belief that larger objects must always be hotter. Such reasoning obscures the scientific definition of temperature as a measure of the average kinetic energy of particles (Pratama & Suhandi, 2023).

Other recurring misconceptions include the cold-transfer belief, where students conceptualize “coldness” as a substance that moves from one object to another. Recent evidence suggests

that linguistic and cultural expressions—such as *panas hilang* (heat disappears) or *dingin masuk* (cold enters)—reinforce these alternative conceptions in non-English-speaking contexts (Suhardi & Karimah, 2022; Siahaan et al., 2021). This supports the view that misconceptions are not random errors but coherent frameworks shaped by prior experiences, language, and instruction.

Many studies on physics misconceptions rely on quantitative diagnostic instruments such as concept inventories. However, these instruments reveal the prevalence of misconceptions but often fail to capture the reasoning processes underlying students' ideas. In contrast, qualitative approaches offer deeper insights into how students construct and maintain their conceptual models, highlighting the cognitive, linguistic, and cultural roots of misconceptions (Braun & Clarke, 2021; Métioui, 2023; Wicaksono et al., 2020).

In the Indonesian context, empirical studies on misconceptions related to heat and temperature remain limited. Recent research shows that Indonesian

students exhibit similar patterns of thinking as those reported globally, with cultural-linguistic factors exerting a notable influence on their reasoning (Siahaan et al., 2021; Pratama & Suhardi, 2023; Suhardi & Karimah, 2022). Similar misconceptions have been documented among Indonesian students using three-tier diagnostic tests (Sari, Yulianti, & Hidayat, 2020), indicating that difficulties in distinguishing between heat and temperature persist despite formal instruction. Therefore, a deeper qualitative investigation is needed to reveal not only the forms of misconceptions but also the reasoning, analogies, and explanatory models that underlie them.

Accordingly, this study aims to investigate senior high school students' conceptual understanding of heat and temperature using a qualitative approach. Specifically, it seeks to (1) identify dominant misconceptions held by students, (2) explore the underlying reasoning behind these misconceptions, and (3) provide instructional implications for teachers to diagnose and remediate

conceptual difficulties. By focusing on the depth rather than the frequency of student responses, this research contributes to a more comprehensive understanding of students' reasoning about thermal phenomena and informs strategies for conceptual change in physics education.

METHOD

Research Design

This study employed a qualitative exploratory design situated within the constructivist paradigm. The qualitative approach was selected because the aim was not to measure the prevalence of misconceptions, but rather to explore students' reasoning processes and uncover the explanatory frameworks underlying their understanding of heat and temperature. According to Merriam and Tisdell (2016), qualitative methods are well suited to studies that focus on meaning-making, interpretation, and context. Instead of testing hypotheses, the present study sought to document the diversity of students' ideas and to identify recurring themes that reveal their conceptual models.

The exploratory orientation provided flexibility to follow unexpected but meaningful directions during data collection. In practice, this meant that although the interviews were guided by a protocol, probing questions were adjusted depending on students' responses. This approach allowed misconceptions to surface in students' own words and metaphors, producing richer data than would have been possible with a purely structured format.

Context and Participants

The research was conducted in a public senior high school in Central Java, Indonesia, which follows the national curriculum for science education. Physics is a compulsory subject in Grade XI (age 16–17), and the concept of heat and temperature is taught as part of the broader thermodynamics unit.

A total of 30 students participated in the study. Participants were selected using purposive sampling with the following criteria: (1) students had completed classroom instruction on heat and temperature, and (2) students represented a range of achievement levels as indicated by teacher

evaluations. The sample consisted of 17 females and 13 males.

To ensure ethical compliance, permission was obtained from the school principal, and informed consent was secured from students and their guardians. All participants were assured that their academic standing would not be affected by their participation, and pseudonyms were used in transcripts and reporting to maintain confidentiality.

Instruments

Two complementary instruments were developed to explore students' conceptions: a conceptual diagnostic test and a semi-structured interview. The conceptual diagnostic test consisted of eight open-ended questions aimed at exploring common misconceptions related to heat and temperature. The items were adapted from instruments previously validated in physics education research and aligned with the Indonesian curriculum. Diagnostic test items were designed based on a previously validated four-tier instrument (Kusairi, Yulianti, & Suyanto, 2021), ensuring that each question effectively captures different levels of conceptual

understanding. Each question requires students to provide an answer and justification for their reasoning to be analyzed in depth. Example items include questions such as "Why does a metal spoon feel colder than a wooden spoon at the same room temperature?", "If you have a bucket of warm water and a cup of hot tea, which is hotter and why?", and several others. These questions target well-documented alternative conceptions of heat transfer, temperature, and particle motion.

Based on the diagnostic test results, twelve students were selected for follow-up semi-structured interviews representing diverse reasoning patterns. Each interview lasted approximately 25–35 minutes and was audio-recorded with participants' consent. The interview protocol contained several guiding questions but allowed flexibility for probing depending on students' responses. Sample interview prompts included "Can you explain what you mean by 'heat flows'?", "What is the difference between heat and temperature in your view?", and "Why do you think larger objects always feel hotter?". During

the interviews, students were also encouraged to draw diagrams or use analogies—such as comparing heat to flowing water—to articulate their conceptual models more clearly.

Data Collection Procedures

Data collection in this study was carried out in three sequential phases, namely the administration of the diagnostic test, the selection of interview participants, and the conduct of the interviews.

In the first phase, the diagnostic test was administered to the participating students during a 40-minute classroom session. The classroom teacher assisted in distributing and collecting the test sheets but did not provide any feedback or guidance while the students worked on the questions. All responses were collected immediately after the session and later scanned for preliminary coding and review.

The second phase involved the selection of students for follow-up interviews. Based on the analysis of the diagnostic test results, twelve students representing a variety of reasoning patterns were chosen. The selection ensured the inclusion of both students who demonstrated

scientifically accurate conceptions and those who exhibited misconceptions. This purposive approach allowed the researcher to capture a wide range of conceptual understandings.

The third phase focused on conducting the semi-structured interviews. Each interview took place individually in a quiet room within the school environment to minimize distractions. Interviews were led directly by the researcher and began with questions related to familiar, concrete thermal phenomena—such as melting ice or boiling water—before progressing to more abstract reasoning about heat and temperature. Throughout each session, the researcher took notes on students' gestures, facial expressions, and any drawings or analogies they used to illustrate their ideas, ensuring that non-verbal cues were included as part of the qualitative data.

Data Analysis

The collected data were analyzed using a thematic coding procedure adapted from Braun and Clarke (2021). First, the interview recordings were transcribed verbatim and the transcripts and diagnostic test

responses were read repeatedly to understand their content. Next, statements were segmented into meaningful units (e.g., "heat stored" or "cold flow") and given initial descriptive codes. These codes are grouped into broader categories and represent misconceptions such as the hot substance model or heat-temperature equivalence.

From these categories, overarching themes were constructed to capture four dominant misconception patterns identified across participants. To ensure the reliability of interpretation, data triangulation was conducted by comparing diagnostic responses with interview transcripts, while validation was achieved through peer review by another physics education researcher to minimize potential bias.

RESULTS AND DISCUSSION

General Findings

The analysis of 30 diagnostic tests and 12 in-depth interviews revealed that students' understanding of heat and temperature is shaped by consistent alternative frameworks. Far

from being isolated mistakes, these misconceptions were systematic, mutually reinforcing, and culturally embedded. Four major categories were identified: (1) Heat as a Substance, (2) Heat–Temperature Equivalence, (3) Cold Transfer Misconception, and (4) Size–Temperature Confusion.

Coding and Categorization of Responses

To organize qualitative data systematically, each participant was assigned a unique code ranging from S01 to S30, corresponding to the 30 students who completed the diagnostic test. These codes were also used to label interview excerpts, allowing the researcher to maintain confidentiality while preserving traceability between the data sources. For instance, "S03" refers to the third student participant. Representative quotes from these coded responses are presented in Table 1, which summarizes the categories of misconceptions, their subthemes, frequency of occurrence, and illustrative student statements.

Table 1. Categories, Subthemes, and Frequency of Occurrence

Category	Subthemes	Frequency (n = 30)	Representative Quote
Heat as a substance	- Heat stored in objects - Heat flows like a fluid - Heat depleted after transfer	22 students	“The cup has heat inside it, and when it cools, the heat comes out.” (S03)
Heat – Temperature Equivalence	- Temperature = total heat - Heat increase means temperature increase automatically	19 students	The bucket must have more temperature because it has more heat.” (S12)
Cold Transfer	- Coldness moves as a substance - Cold ‘pushes away’ heat	14 students	“The ice gives coldness to the water.” (S07)
Size – Temperature Confusion	- Bigger object = hotter - Mass and temperature conflated	11 students	“The bigger pot is hotter than the small bowl.” (S18)

Heat as a Substance

Findings: The most widespread misconception was the idea of heat as a tangible substance. Students described heat as if it were a fluid that could be “stored,” “poured,” or “used up.” To illustrate this finding, Figure 1 presents an authentic student worksheet response collected during the diagnostic phase. The student’s handwritten answers clearly reflect the belief that heat behaves as a material substance that can be contained and transferred between objects, aligning with the “Heat as a Substance” misconception category.

Analysis: This conception mirrors the historical caloric theory, which portrayed heat as a material substance that can be stored or transferred. Although this model was scientifically abandoned, recent research shows that students continue to adopt similar substance-based reasoning because it simplifies abstract thermal processes into intuitive, everyday schemas. Muñoz Contel et al. (2016) (2016) noted that students often interpret heat as a flowing fluid, while Métioui (2023) emphasized that such conceptions persist even after conceptual-change instruction. The

endurance of these ideas indicates that students’ everyday language and experiences—such as expressions like “heat flows” or “losing heat”—play a

major role in reinforcing these intuitive yet scientifically inaccurate frameworks.

STUDENT WORKSHEETS
Concept of Heat and Temperature

Reflective Questions
Write your responses in your own words as clearly as possible. There are no right or wrong answers, this worksheet aims to explore your reasoning about the concepts of heat and temperature.

What is Heat?		
No	Reflective Questions	Student Answers
1.	Where does the heat go when a cup of hot water becomes cold after a while?	The heat goes out and disappears into the air.
2.	Why does a metal spoon feel colder than a wooden spoon at the same room temperature?	Because the metal has more heat inside, and when I touch it, the heat flows into my hand until it is gone.
3.	When hot water is poured into a glass, what happens to the heat?	The heat moves and fills the glass like water being poured.
4.	Can heat be kept or stored inside an object? Explain your answer.	Yes, objects can store heat just like a container keeps water.
5.	If you combine two hot liquids together, where does the extra heat go?	The heat from both adds up and stays inside the mixture.
6.	What happens to heat when something burns and becomes ash?	The heat has been used up completely.
7.	When an object becomes cool, does it still contain heat?	No, the heat has all gone out, so the object has no heat anymore.
8.	Why does heat stop flowing between two objects at the same temperature?	Because both objects already have the same amount of heat inside.

Figure 1. Student Worksheet Showing Students’ Handwritten Explanations that Reflect the “Heat as a Substance” Misconception.

Pedagogical Implication: Teachers need to emphasize that heat is not stored, but rather an energy in transit due to temperature difference. Visualization through particle simulations can help students shift from substance-based thinking to a kinetic energy transfer model.

Heat–Temperature Equivalence

Findings: Nearly two-thirds of the students equated heat with

temperature, assuming that more heat implies higher temperature.

1. “The big bucket must have higher temperature than the cup, because it contains more heat.” (S12)
2. “If you add heat, the temperature always goes up. Heat and temperature are the same thing.” (S20)

To support these findings, a portion of students’ handwritten

responses was collected through a reflective worksheet designed to explore their conceptual understanding of heat and temperature. The worksheet contained open-ended questions asking students to explain everyday

thermal phenomena in their own words. Many responses revealed the same misconception that temperature directly depends on the total amount of heat, rather than on the average kinetic energy of particles.

STUDENT WORKSHEETS
Concept of Heat and Temperature

Reflective Questions
Write your responses in your own words as clearly as possible. There are no right or wrong answers, this worksheet aims to explore your reasoning about the concepts of heat and temperature.

Heat-Temperature Equivalence	
No	Student Answers
1. Which has a higher temperature: a small cup of boiling water or a large bucket of warm water? Explain your answer.	"The bucket, because it has more heat, so it must be hotter"
2. If you heat an object longer, does its temperature always continue to increase? Why or why not?	"Yes, because the more heat added, the higher the temperature"
3. When two objects of different sizes are heated for the same amount of time, which one will be hotter?	"The bigger one, because it absorbs more heat"
4. Does an object that contains more heat always have a higher temperature? Explain your reasoning.	"Yes, because heat and temperature are the same thing"
5. If two cups of water are at the same temperature but one has more volume, does it have more heat?	"Yes, the larger cup has more temperature because it has more heat"
6. When an object cools down, does it lose temperature or lose heat?	"It loses both, because they are the same"
7. Can something be hot but contain less heat than another object? Give an example.	"No, that's impossible, hot means it has more heat"
8. Why does boiling water stay at the same temperature even when heat keeps being added?	"Because, it already has too much heat and cannot get hotter"

Figure 2. Excerpt from Students' Handwritten Worksheet Responses Showing the "Heat–Temperature Equivalence" Misconception

Analysis: This misconception reveals confusion between extensive (heat, dependent on mass and substance) and intensive (temperature, independent of mass) properties. Recent research confirms that many students fail to distinguish the quantity of energy transferred from the average kinetic energy of particles. Yulianti,

Kusairi, and Suyanto (2022) found that learners frequently equate larger quantities of heat with higher temperature, while Métioui (2023) emphasized that such reasoning persists even after explicit instruction. Similarly, Muñoz Contel et al. (2016) reported that this conflation remains one of the most resistant

misconceptions in thermal physics education, indicating the need for explicit teaching on the distinction between heat and temperature. This difficulty in connecting macroscopic and microscopic views is consistent with findings by Karim, Maries, and Singh (2018), who noted that many learners fail to link particle-level reasoning with observed temperature changes.

Pedagogical Implication: Teachers should use contrastive experiments, e.g., comparing a small cup of boiling

water and a large bucket of warm water: the cup has higher temperature but less total heat. This helps clarify that temperature is not proportional to the total heat content.

Cold Transfer Misconception

To provide clearer evidence of this finding, Figure 3 presents an authentic excerpt from a student worksheet collected during the diagnostic activity. The worksheet was designed with reflective questions that prompted students to explain everyday thermal phenomena.

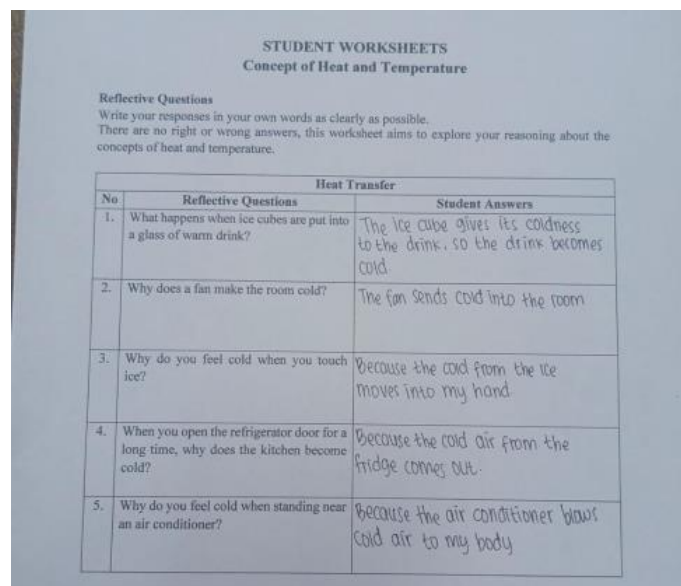


Figure 3. Excerpt from a Student Worksheet Showing Handwritten Responses that Reflect the Cold-Transfer Misconception.

As shown in the handwritten responses, students frequently described “coldness” as a moving entity that transfers into warmer

objects—for example, “The ice cube gives its coldness to the drink” and “The fan sends cold into the room.”

These responses vividly demonstrate the persistence of the cold-transfer misconception, in which “cold” is perceived as a tangible substance rather than as the absence of heat flow.

Analysis: This misconception is rooted in linguistic framing. In Indonesian (as in many languages), everyday expressions treat “cold” as a substance (*es memberi rasa dingin*). Wiser and Carey (1983) highlighted that such language promotes the idea of cold transfer, making it culturally reinforced.

Pedagogical Implication: Teachers should deliberately reframe classroom discourse, emphasizing that only heat transfers from hot to cold regions. Instruction should also incorporate molecular models (particles slowing down, not “adding cold”) to replace this erroneous metaphor.

Size–Temperature Confusion

Findings: A smaller but significant group (11 students) believed that larger objects are automatically hotter than smaller ones. To further illustrate this reasoning pattern, Figure 4 presents an excerpt from a student

worksheet showing how learners associate object size with temperature. Students’ written explanations reflect the belief that larger objects “store more heat” or “absorb more heat,” indicating confusion between heat capacity and temperature. **Analysis:** Students conflated heat capacity with temperature, applying the intuitive heuristic that “bigger means hotter.” This misconception reflects difficulty in distinguishing between total thermal energy and average particle energy. Recent studies have confirmed similar reasoning patterns: Yulianti, Kusairi, and Suyanto (2022) found that many high-school students equate object size with higher temperature, while Métioui (2023) reported that such confusion remains prevalent even after formal instruction, indicating that this misconception persists across cultural and educational contexts.

Pedagogical Implication: Classroom activities should contrast heat vs. temperature explicitly, e.g., comparing heating rates of equal vs. unequal masses of different materials. This can reveal that larger mass does not guarantee higher temperature rise.

STUDENT WORKSHEETS
Concept of Heat and Temperature

Reflective Questions
Write your responses in your own words as clearly as possible.
There are no right or wrong answers, this worksheet aims to explore your reasoning about the concepts of heat and temperature.

Relationship between Object Size and Temperature		
No	Reflective Questions	Student Answers
1.	Two pots—one large and one small—are placed on the same stove. Which pot becomes hotter first? Why?	The big one. The big pot, because it's larger so it gets more and becomes hotter
2.	When you compare a big candle flame and a small candle flame, which one has a higher temperature? Explain.	The big one, because it looks stronger and gives more heat
3.	If you heat a large block of metal and a small nail for the same time, which will be hotter?	The large The large block because it absorbs more heat and thus have higher temperature
4.	When you touch a big pan and a small pan after heating, which one feels hotter? Why?	The big one, because it stores more heat
5.	Does a bigger object always mean it has more temperature?	Yes, because more size means more heat and more temperature
6.	If two objects are made of the same material but different sizes, will they always have different temperatures? Why or why not?	Yes the bigger one must be hotter because it has more heat inside

Figure 4. Student’s Handwritten Worksheet Showing Responses that Reflect the Size–Temperature Confusion Misconception.

Comparison with Previous Studies

The The results of this study are consistent with recent research on students’ misconceptions in thermal physics. Muñoz Contel et al. (2016) reviewed diagnostic instruments across multiple countries and confirmed that substance-based reasoning about heat is a common and persistent misconception. Similarly, Métioui (2023) analyzed recent studies in thermodynamics and found that many students still view heat as a stored material rather than energy in

transit, indicating the resilience of intuitive mental models.

Research within Southeast Asia has also highlighted comparable reasoning. Yulianti, Kusairi, and Suyanto (2022) reported that Indonesian high school students often conflate heat with temperature when responding to four-tier diagnostic questions, revealing similar confusion between extensive and intensive properties. In addition, Wicaksono, Sutopo, and Kaniawati (2020) conducted a qualitative exploration and found that learners tend to

describe heat transfer using analogies of fluid flow—consistent with the present study’s findings. Together, these results support the conclusion that misconceptions regarding heat and temperature remain conceptually robust across different educational systems and languages, even in contexts with curriculum reforms emphasizing inquiry based instruction.

Pedagogical Implications

The findings of this study offer several pedagogical implications for improving the teaching and learning of heat and temperature in physics classrooms. First, teachers should employ particle-level visualizations to help students connect macroscopic phenomena with the microscopic motion of particles. Such visual representations can clarify that temperature corresponds to the average kinetic energy of particles rather than the total amount of heat contained in an object.

Another effective strategy is the use of Predict–Observe–Explain (POE) activities, for example by comparing a cup of hot water and a bucket of warm water to challenge students’ belief that larger quantities always possess higher

temperature. These activities promote conceptual conflict and provide opportunities for students to reconcile everyday experiences with scientific reasoning. Inquiry-based learning has also been shown to reduce misconceptions about heat transfer (Utami & Rachmadtullah, 2022), supporting the importance of hands-on exploration in conceptual change.

In addition, linguistic reframing is crucial in addressing misconceptions that are reinforced by language. Teachers should avoid expressions such as “cold enters” or “heat disappears” and instead emphasize the scientifically accurate description that “heat leaves the system”. Language used in classroom discourse plays a central role in shaping conceptual understanding, particularly in multilingual contexts such as Indonesia.

Furthermore, contrastive experiments that decouple size from temperature—such as comparing equal heating of different masses—can help students differentiate between the concepts of heat capacity and temperature. By observing that larger objects do not necessarily have higher

temperatures, students can reconstruct more accurate thermal reasoning.

Finally, conceptual dialogue should be integrated into instruction to encourage students to articulate their reasoning and engage in peer critique. Allowing students to discuss and reflect on their explanations enables teachers to surface misconceptions and guide learners toward scientifically consistent models of heat transfer and temperature.

Encouraging metacognitive reflection can also help students reconstruct their conceptual understanding (Zohar & Barzilai, 2021), further supporting long-term conceptual change through awareness of their own thinking processes. Collectively, these strategies provide teachers with practical approaches for fostering conceptual change and promoting deeper understanding of thermal phenomena.

CONCLUSION

This qualitative research investigated senior high school students' conceptual understanding of heat and temperature through diagnostic tests and semi-structured interviews. The findings revealed that

students' ideas were not random mistakes but represented systematic and coherent alternative conceptions. Four dominant misconceptions were identified: the belief that heat acts as a tangible substance that can be stored or consumed; the assumption that temperature equals the total amount of heat; the idea that coldness itself transfers between objects; and the confusion that larger objects must always be hotter. These misconceptions align with international reports but also highlight the role of linguistic and cultural metaphors—such as everyday expressions of “cold entering” or “heat disappearing”—in shaping Indonesian students' reasoning about thermal phenomena.

Aligned with the research objectives, this study not only documented these misconceptions but also explored the reasoning processes underlying them. The results indicate that misconceptions about heat and temperature are deeply rooted, coherent, and resistant to traditional instruction, emphasizing the need for conceptual restructuring through

purposeful and inquiry-based learning strategies.

Pedagogically, the study underscores several implications for classroom practice. Teachers should integrate particle-level representations to help students visualize temperature as the average kinetic energy of particles, employ Predict–Observe–Explain (POE) activities to challenge intuitive but incorrect beliefs, and reframe classroom language to avoid reinforcing everyday metaphors of “cold transfer.” Furthermore, contrastive experiments that separate the concepts of mass, heat, and temperature can clarify distinctions between heat capacity and temperature, while conceptual dialogue can encourage students to articulate reasoning and confront their misconceptions collaboratively.

In conclusion, addressing misconceptions of heat and temperature requires more than correcting definitional errors—it demands conceptual change through carefully designed instruction. By acknowledging the alternative frameworks students hold and providing meaningful, context-based

learning experiences, educators can guide learners toward scientifically accurate conceptions of heat, temperature, and energy transfer.

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