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Identifying Student Misconceptions Using Three-Tier Test with Certainty of Response Index on Temperature and Heat Topics

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Abstract

This research aims to identify students' misconceptions using a Three-Tier diagnostic test assisted by the Certainty of Response Index (CRI) on temperature and heat material. The data analysis method used in this research is quantitative descriptive and equipped with a three-tier Certainty of Response Index (CRI). The population in this study was class XI 1 IPA MAN 1 Musi Banyuasin with 30 students, and the sample in this study was class. Data collection techniques were used during the observation, test, and documentation stages. The research results showed that the misconceptions identified regarding the concept of temperature and heat were 40%, 36% understood the concept, 6% understood the concept but needed clarification and 18% needed to learn the concept. The misconceptions experienced by students are classified as moderate-level misconceptions with a percentage range of 31% ≥ 60%. The cause of misconceptions is the students' errors in learning context and incomplete reasoning. It is hoped that the results of this research can provide information about misconceptions that occur in the matter of temperature and heat and can serve as a guide for further research to find out the causes of misconceptions and efforts to overcome them.

INTRODUCTION

Physics is one of the branches of science that studies the symptoms of nature and the systematic phenomena that form the basis of the development of science and technology. Physics learning emphasises the knowledge of facts and the preservation of formulas, which an understanding of basic concepts must accompany. Students must be actively involved in the learning process to acquire knowledge and concepts of physics fully [1]. The student's learning process is directed to understand the learning material optimally. However, the fact is that the students do not fully master the material well taught, primarily in physics lessons that contain many complex scientific concepts [2].

Based on the results of interviews with physical subject teachers at MAN 1 Musi Banyuasin, it was found that some students still struggle to understand concepts, leading to the occurrence of misconceptions, which in turn resulted in low learning outcomes in the physics subject. The teacher also mentioned that misconceptions can impact the learning process, making it difficult for students to comprehend and respond to the questions posed by teachers, thereby influencing the overall learning outcome. Because the concept relates to something abstract, it's quite natural [3]

Aprilanti, et al [4] asserts that misconceptions or errors in understanding can lead to poor learning outcomes in students, Misconception not only impact the current cocncept under study, but also influencer subsequent concepts in physics due to their interdependence. Several sources, such as student, teachers, textbooks, context, and teaching methods, can contibutribute to misconceptions [5]. How to identify misconceptions uses various methods, namely interviews, presentation of concept maps, diagnostic tests and the Certainty Response Index (CRI). The research by Hasan Saleem et al. [6] titled "Misconceptions and the Certainty of Response Index (CRI)" suggests that it can be challenging to distinguish between students who experience misconceptions and those who do not understand concepts. Therefore, they have created methods to differentiate between the two. The research shows that CRI methods are effective in diagnosing students who do not comprehend concepts and students who suffer from misconceptions [6]. When applying such methods, it is crucial to observe students' honesty in answering the certainty and response index, as CRI can identify both types of students based on their confidence level. Additional research by Atsilah et al. [7], titled Development of a Three-Tier Test Multiple Choice to Identify Misconceptions on Newton's Law Matter, revealed that the average presentation misleads students on the Newton Law material by 30%, students understand concepts by 53%, and students who do not understand the concept by 18%.

Three-tier multiple choice is a series of questions consisting of three levels. The first level contains a duplicate-choice question, while the second level consists of questions determining the reason for the first-level answer. The third level includes questions that confirm the previous question's answer. In addition to recognizing students who understand concepts and misconceptions, three-tier diagnostic tests can also recognize students who do not understand conceptions. However, using three-tier multiple-choice diagnostic tests does not always accurately distinguish between students who experience misconceptions and students who do not understand the concepts. Therefore, to address the weakness of three-tier multiple choice, we added the CRI method to measure the student's confidence level. Hasan et al. [6] developed the CRI technique, which measures the respondents' level of confidence or certainty in answering each given question. Based on the previously outlined background, the researchers conducted a study to identify misconceptions among students. The researchers employed a Three-Tier Diagnostic Test, which included a Certainty of Response Index, to identify students' misconceptions about the physical disclosure of topics. Temperature and Calor aimed to identify misconceptions among students on the concepts of temperature and calor, particularly in class XI IPA I MAN 1 Musi Banyuasin.

RESEARCH METHODS

This research uses both descriptive and quantitative methods. On March 5, 2021, we conducted a study at MAN 1 Musi Banyuasin. The sample used was 30 students in the XII grade of IPA 1. The preparation phase of the examination is conducted through observation in the school to find out the problems experienced by the students. Preparation stage of the instrument using a three-tier multiple-choice diagnostic test. Each question will be given five choice answers, five choice reasons, and the belief of the answer using CRI. The research is carried out by identifying the learning process by providing questions that are supplemented with the diagnostic there tier test with CRI assistance. The main stage is the processing and analysis of data to discover misconceptions occurring in students.

The technique of data collection through observation involves conducting interviews with physics teachers about temperature and caloric matter and looking at the students' learning outcomes. The test is a series of questions or exercises used to measure the skills of knowledge, intelligence, abilities, or talents possessed by an individual or group [8]. Teachers use this test to gauge the student's comprehension of temperature and caloric matter. Teachers most commonly use a double-choice test format. In this study, researchers will use a three-tier multiple-choice test with a total of 20 questions on temperature and calor topic. Here's the distribution table of temperature and calories (Table 1):

Table 1. Distribution of temperature and heat questions

Concept	**Question Number**
Temperature	1,2,3,4,5,6
Heat and temperature changes	7,8,9,10
Heat and changes in state of matter	11,12,1314
Azaz Black	15,16,17
Transport of Calor	18,19,20

Next, the assessment scale for CRI is accompanied by objective test questions, namely, the first level is a question with one correct answer, the second level is a reason for the first answer with one answer and four distracting answers, and the third level is confidence in the student's answer using CRI. For students' confidence level, the extent of students' understanding of the concept being tested can be seen from the scale chosen by students. Table 2 is an assessment scale of CRI [9] :

Table 2. CRI Assessment Criteria

CRI	Criteria	**Confidence Level**
0	Guess Answer	
1	Almost Guess Answer	Low/Not sure
2	Answer Not Sure	
3	Answer Sure	
4	Almost Correct Answer	High/Confident
5	Answer is Definitely Correct	

Analysis of students' misconceptions is carried out to obtain misconception data by calculating the percentage of misconceptions, namely as follows:

$$P = \frac{F}{N} \times 100\% \tag{1}$$

where P is the percentage of students who have misconceptions, F is the number of students who have misconceptions, and N is the total number of test-takers.

The data in this research is quantitative. The quantitative data was obtained from the results of a three-tier diagnostic test accompanied by the Certainty of Response Index (CRI). The following are the criteria for assessing students' understanding using the Modified Certainty of Response Index (CRI) technique [10]:

Table 3. Criteria for assessing students' understanding of the CRI Modification Technique

Answer	Reason	Score of CRI	Description	Alias
Correct	Correct	>2,5	Understand the Concept	PK
Correct	Correct	<2,5	Understand the concept but not sure	PKKY
Correct	Wrong	>2,5	Misconceptions	M
Correct	Wrong	<2,5	Don't Know the concept	TTK
Wrong	Correct	>2,5	Misconceptions	M
Wrong	Correct	<2,5	Don't Know the concept	TTK
Wrong	Wrong	>2,5	Misconceptions	M
Wrong	Wrong	<2,5	Don't Know the concept	TTK

After categorizing the test results and calculating the percentage in each category (P), the percentage of students' misconceptions is categorized based on the following Table 4 [11]:

Table 4. Misconceptions Percentage Category Grouping

Percentage	**Category**
0% ≥ 30%	Low
31% ≥ 60%	Midle
61% ≥ 100%	Hight

The results of students' answers on an objective test in the form of a three-level multiple choice accompanied by a CRI scale can reveal which students understand the concept, students who do not understand the concept and students who experience misconceptions about temperature and heat topic.

RESULT AND DISCUSSION

Students experiencing misconceptions or not understanding concepts can be distinguished by looking at whether the answer to a question item is correct and looking at the high or low certainty index of the CRI answer. The research results show that the identification of students' misconceptions using a three-tier multiple choice test accompanied by CRI varies significantly between the percentage of students who understand the concept, understand the concept but are not sure, have misconceptions, and do not understand the concept in each question item. The percentage of student misconceptions in each sub-concept of temperature and heat is presented in Table 5.

Table 5. Distribution of Student Misconceptions on Subconcepts

No.	**Subconcept**	**Persentage**	**Misconceptions Category**
1.	Temperature	44,4%	Midle
2.	Heat and temperature changes	41,7%	Midle
3.	Heat and changes in state of matter	36,7%	Midle
4.	Azaz Black	43,3%	Midle
5.	Transport of Calor	31,3%	Midle

Based on Table 5, the overall misconception category in the 5 sub-concepts of temperature and heat is included in the moderate misconception category. The sub-concept with the highest percentage of misconceptions is the temperature sub-concept at 44.4%, while the lowest is the heat transfer sub-concept at 31.3%. Students experienced many misconceptions in the temperature sub-concept; the indicator re-expressed the definition of temperature at 60%. In contrast, students who experienced the lowest misconceptions in the heat transfer sub-indicator identified heat transfer by conduction, convection and radiation, namely 40%. Table 6 shows the distribution of students' conceptual understanding.

Table 6. Distribution of Conceptual Understanding of Each Question Item

Question Number	**Category**							
	Understand the Concept		**Understand the Concept But Not Sure**		**Misconceptions**		**Don't Know the Concept**	
	f	**%**	***f***	**%**	***f***	**%**	***f***	**%**
1	3	10	2	6,7	18	60	7	23,3

2	12	40	0	0	13	43,3	5	16,7
3	8	26,7	3	10	15	50	4	13,3
4	14	46,7	2	6,7	12	40	2	6,7
5	7	23,3	3	10	15	50	5	16,7
6	13	43,3	3	10	7	23,3	7	23,3
7	21	70	1	3,3	5	16,7	3	10
8	9	30	1	3,3	14	46,7	6	20
9	6	20	0	0	16	53,3	8	26,7
10	7	23,3	3	10	15	50	5	16,7
11	11	36,7	4	13,3	10	33,3	5	16,7
12	12	40	2	6,7	11	36,7	5	16,7
13	6	20	1	3,3	15	50	8	26,7
14	10	33,3	3	10	8	26,7	9	30
15	11	36,7	3	10	12	40	4	13,3
16	12	40	2	6,7	13	43,3	3	10
17	11	36,7	1	3,3	14	46,7	4	13,3
18	11	36,7	0	0	12	40	7	23,3
19	8	26,7	3	10	8	26,7	9	30
20	16	53,3	1	3,3	8	26,7	5	16,7
Total	210	36,3	38	6,3	241	40,16	111	18,5
Criteria	Middle		Low		Middle		Low	

Table 6 shows that the average misconception of the 20 questions is 40%, and it is included in the medium category. The highest student misconceptions were in question number 1, with a percentage of 60%, while the lowest misconceptions experienced by students were in question number 7, with 16.7%. Apart from that, the average number of students who understand the concept and understand the concept but need help understanding it are 36.3%, 6.3%, and 18.5%, respectively.

Question number 1 was used to identify the temperature concept. In this study, we found the students experienced misconceptions on question number 1, namely 18 people, with a 60% percentage. Students who experience misconceptions assume that temperature is a measure of heat or heat. Of course, their answer is incorrect because the temperature is only sometimes hot. Kesidou and Duit [12] stated that the average student aged between 15 - 16 years thinks that temperature is the sum of the amount of heat. In other words, temperature is considered a measure of the amount of heat. The correct concept is that temperature is an object's degree of hotness or coldness [13].

The student's understanding of an object's thermometric properties was identified using Question 2. This study showed the students who experienced misconceptions, namely 13 people with a percentage of 43%. This misconception occurred because students thought that if an object were cut into two parts, the temperature would change. After all, the answer was that, according to the zero law of thermodynamics, if an object were cut into several parts with different sizes, the temperature would be different. The actual concept is that according to the law of thermodynamics 0, if object A has the same temperature as object B and object B will have the same temperature as object C, meaning that when the object is cut into several parts, the temperature will remain the same.

The concept of temperature comparison of particular objects is identified by using Question 3. This study revealed that 15 people, or 50%, of the students experienced misconceptions. Students assume that changes in the temperature of an object do not depend on the environment. In the explanation question, it is written "if environmental influences are ignored", but the correct answer is not that the change in temperature of an object does not depend on the shape or size of an object. Students immediately choose answers according to the information in the question but must analyze the event first..

Question 4 was used to identify the student's ability to calculate temperature on the Celsius to Kelvin scale. Students experienced misconceptions in question number 4, namely 12 people, with a percentage of 40%. Students assume that writing the unit kelvin is added with degrees (º). The concept is that the international system (SI) temperature unit is expressed in degrees (º) and removed in units of Kelvin or K, not degrees Kelvin or °K. So, to convert temperature on the Celsius scale to Kelvin, use the formula $t + 273K$.

Question number 5 was used to identify the concept of the relationship between the Celsius scale and the Fahrenheit scale. Students experienced misconceptions in question number 5, namely 15 people, with a percentage of 50%. Students still need to improve in using formulas. Each temperature on the Celsius scale corresponds to a specific temperature on the Fahrenheit scale. That 0ºC is the same as 32ºF and the range of 100º on the Celsius scale is the same as the range of 180º on the Fahrenheit scale. Thus, one degree Fahrenheit (1ºF) equals 100/180 = 5/9 degrees Celsius (1ºC). The conversion between these two temperature scales can be written $C = \frac{5}{9}(F - 32)$ [14].

The student's understanding of the coefficient of linear expansion of various types of metal is identified by using question 6. As seen in Table 6, 7 students experienced misconceptions in question number 6, with a percentage of 23.3%. Students can analyze based on the table given and find the correct answer, but they need to be corrected to determine the length expansion formula.

The student's understanding of heat is identified by using question 7. Five students experienced misconceptions, with a percentage of 17%, and 21 students understood the concept, with a percentage of 70%. In this question, not many students experience misconceptions, and most students already understand the definition of heat, namely energy transferred from one object to another due to a difference in temperature.

In question number 8, understanding the concept of the heat change process will be identified. Fourteen students experienced misconceptions in question number 8, with a percentage of 47%. Students understand that there will be a temperature change if an object receives or releases heat, but they are wrong in giving reasons. They assume that temperature changes occur because the temperature moves from one object to another. Of course, this kind of understanding is wrong; temperature changes occur due to the heat received or released. Namely, heat is heat energy that can affect the object's temperature.

Students' understanding of objects that receive heat is identified using question number 9. Question number 9 revealed misconceptions among 16 students, accounting for 53.3% of the total. Some students understand that if two objects are heated for a while and have different sizes, the heat of the larger object will be higher. However, students incorrectly assumed that because ball A was more significant than ball B, ball B would absorb more heat. The actual concept is that when ball b is less significant than ball a, it absorbs less heat.

Students' understanding of the value of the heat capacity is identified using question number 10. As seen in Table 6, 15 students experienced misconceptions in question number 10, with a percentage of 50%. Students understand that at the first level, the factors that influence the heat capacity value of an object are density and specific heat. However, students are confused at the second level; they use the formula Q=mcΔT, C (heat capacity), which can be found by multiplying ΔT by c(heat). That answer is not correct, where you should multiply m by c.

Questions 11 and 12 identify an understanding of changes in the state of matter. Ten students experienced misconceptions in question number 11, with a percentage of 17%, and 21 students understood the concept with a percentage of 33%. Students assume that when boiling water is heated continuously, the temperature will rise, and choose the reason that the heat received by the water increases the temperature and is used to change the state of the substance. If students understand the concept, why does boiling water have a constant temperature if heated? The heat the water receives is not used to increase the temperature but to change the liquid state into steam. In question number 12, there were 11 people with a percentage of 37.7%. Students need to be more precise in understanding how to change the state of matter in the picture.

Question 13 identifies the concept understanding of the amount of energy that must be released in the refrigerator. Fifteen students experienced misconceptions in question number 9, with a percentage of 50%. Students need help understanding how to calculate the energy that must be released in the refrigerator.

Question 14 identifies the concept understanding of an example of a process of changing form that releases heat. Eight students experienced misconceptions on question 14, with a percentage of 26.7%. Students assume the process of changing the state of a substance that releases heat is freezing and evaporating; in reality, the form of a substance that releases heat is freezing and condensing.

The concept understanding of students of the heat equation is identified by using question 15. Twelve students experienced misconceptions in question 15, with a 40% percentage of students experiencing misconceptions. Students were not precise in answering the first-level questions, but based on their answers, they understood how to find the temperature of the mixture using the formula $Q_{out} = Q_{in}$.

Students' understanding of the concept of temperature changes when objects touch was identified using questions 16 and 17. 13 students experienced misconceptions with a percentage of 43%. Students are wrong in answering why heat will flow instantly from hot to cold, even though the center of gravity is at the temperature difference. Meanwhile, 14 students experienced misconceptions in question number 17, with a percentage of 47%. Students assume that if there is excess heat at the left end of the metal, the heat will move to the other end and cause the hand to feel hot. This misconception is incorrect; the correct concept is that heat flows from one end to the other. Heat conduction only occurs if there is a temperature difference, and the heat flow through an object will be proportional to the temperature between its edges.

Questions 18, 19, and 20 are used to identify students' conceptual understanding of heat transfer. Students experienced misconceptions in question number 18, namely 12 people, with a percentage of 40%. Students feel that they understand how to answer this question, even though they experienced clarifications of the various heat transfer processes. Students experienced misconceptions in question number 19, namely 8 people, with a percentage of 26.7%. Students assume that soldering is an example of heat transfer by convection, even though this is soldering as an example of heat transfer by conduction because electric solders will receive heat from electrical conversion. The heat from this electrical energy will be transmitted to the metal tip of the solder, which is touched by the tin and positioned at the feet of the electronic components being placed. There were 8 students experiencing misconceptions in question number 20, with a percentage of 26.7%, and 16 students understanding the concept, with a percentage of 53%. Half of the sample had the correct answer to this question and understood that white was a good color for house paint. This misconception is based on the Stefan-Boltzmann equation. Factor e, emissivity, is a number between 0 and 1 showing a material's characteristics. Black surfaces, such as charcoal, have an emissivity close to 1, while shiny surfaces are close to zero and thus emit less radiation [14]. That is why lighter/lighter colours are usually preferred over dark ones on warm days; this application is based on the concept of temperature and heat.

Various factors cause misconceptions among students. The most dominating factor is that most students must combine their knowledge with actual concepts. Students do not apply the ideas learned at school in everyday life and tend to explain phenomena with their understanding without seeing the truth. In other words, most of the misconceptions emerge from the students themselves [15].

The concept-understanding tests reveal that students have misconceptions about the concepts of temperature and heat. These misconceptions can arise because students have a low interest in learning. Students who are not interested tend not to listen or pay full attention; they tend to ignore what the teacher says. After discovering the misconceptions students experience about temperature and heat, it is hoped that further research can overcome these misconceptions. Various learning methods and models that actively involve students and teachers as facilitators can be applied to overcome or reduce the possibility of misconceptions.

CONCLUSION

Using a three-tier diagnostic test and the CRI on temperature and heat material, researchers identified 40% of students' misconceptions on the concept of temperature and heat as a whole, 36% on understanding the concept, 6% on understanding the concept but not sure, and 18% on not knowing the concept, placing them in the low misconception category the sub-concepts that experience misconceptions regarding temperature and heat are 44.4% of the temperature sub-concept, 41.7% of the heat and temperature changes sub-concept, 36.7% of the heat and changes in the state of matter, 43.3% of the black principle sub-concept, and 43.3% of the sub-concept of heat and changes in the state of matter. The heat transfer sub-concept is 31.3%.

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