



High School Students' Misconceptions on Materials of Temperature and Heat Using Three-Tier Diagnostic Tests Assisted by Live Worksheets

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Abstract

This study aims to discover the misconceptions experienced by high school students on the material of temperature and heat. This type of research is descriptive quantitative. The sample of this research is XI science students at MAN 1 Samarinda and SMA Negeri 2 Samarinda, with 80 students. Research data were collected using tests. This type of test is a three-tier diagnostic test with three levels of answer choices, including questions and answer choices, reasons for answering, and confidence in answering. Overall, the results showed that students had misconceptions of 43.4%, which were classified as medium category misconceptions. Based on the misconceptions obtained, The misconceptions identified in the overall temperature and heat material are 43,36%, the percentage of understanding concepts is 34.75%, the percentage of only guessing is 8.67%, and the percentage of only guessing not understanding concepts is 13.08%. The percentage of misconceptions obtained includes the concepts of temperature and heat in the medium category level.

Keywords: misconception; three-tier diagnostic test; temperature and heat

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INTRODUCTION

Mastery of abstract concepts in physics often creates difficulties compared to more real (concrete) concepts. This causes students to make often their understanding of a concept being studied. However, sometimes the results of understanding are not as they should be (Fariyani et al., 2015). We can call this discrepancy a misunderstanding of the concept or a misconception

The misconception is an understanding of a concept that is not by following per under the actual concept (Muna, 2016).

Teachers need to pay attention to the existence of misconceptions that exist in students, and this is because misconceptions can cause students to fail in the learning process (Yuliati, 2017). Misconceptions are difficult to overcome because misconceptions are never measured either in the learning process or during exams. The exams or tests used are mostly multiple-choice; this can make every student who has misconceptions can also answer correctly. Students may answer but do not know the truth of the answers



obtained; the exams held only require students to choose an answer but never know whether the answer is right or wrong. So that students can guess the answer without knowing the correct concept (Jumini *et al.*, 2017).

Analysis of students' misconceptions becomes important for effective physics teaching. Rahayu *et al.* (2018) said that one of the basic efforts to find out the truth of the concepts students have is to make a diagnosis in the form of a test. The type of test that can analyze the difficulties and weaknesses of students is a diagnostic test. This diagnostic test can help find misconceptions that students may experience (Jumini *et al.*, 2017). This test has three levels: the choice of answers to the questions, the reasons for choosing the answers, and confidence in answering the questions. With these levels of questions, the use of this test is expected to detect the existence of misconceptions that exist in students (Jumini *et al.*, 2017).

Jauharyiah *et al.* (2018) stated that using the Three-Tier Diagnostic Test to detect misconceptions is more effective than other diagnostic instruments because the use of the three-tier diagnostic test can detect the location of the misconceptions that occur in students. In another study, Febrianti (2018) stated that the Three-Tier Diagnostic Test is the most effective assessment for diagnosing student misconceptions than the multiple-choice test, which only has two levels. The Three-Tier Diagnostic Test accurately detects students' misconceptions with their lack of knowledge or level of trust. Susilaningsih *et al.* (2020) also state that one of the instruments that can measure students' misconceptions is the Three-Tier Diagnostic Test. Based on several previous studies, it can be stated that the use of the Three-Tier Diagnostic Test is proven to be able to detect misconceptions experienced by students.

Many other researchers have used the Three-Tier Diagnostic Tests method, including using CBT (Computer Based

Test) (Halim *et al.*, 2018), Two-level diagnostic tests using e-learning and using interactive media (Resta *et al.*, 2020). Meanwhile, the Three-Tier Diagnostic Tests method using live worksheets so far has never been carried out by other research. Therefore, in this study, researchers used the media in live worksheets. Based on this background, the use of the Three-Tier Diagnostic Test assisted by Live Worksheets is expected to analyze students' misconceptions. It is hoped that the research will contribute to solving the problems of misconceptions experienced by students and can be a reference in improving the quality of students' understanding, especially in the field of physics.

METHOD

This type of research is descriptive quantitative. The sample of this study were 40 students of class XI science students at MAN (Islamic Senior High School) 1 Samarinda and 40 students of class XI IPA at SMA. The sample in this study was taken using a non-probability sampling technique. In each school, two classes were selected as samples—class sampling using the purposive sampling technique (Senior High School) Negeri 2 Samarinda. Data were collected using a test technique. The type of test is a Three-tier Diagnostic Test with 45 questions. Three-tier Diagnostic Test in the form of three levels of answer choices, including questions and answer choices, reasons for answering, and confidence in answering. Example "Ayu poured the water that had just been boiling into a large teapot and a small glass simultaneously. How do you think the water temperature in a small glass compares to the temperature of the water in a large pitcher?"

A. The temperature of the water in the small glass is higher than the

- temperature of the water in the large jug.
- B. The temperature of the water in the small glass is lower than the temperature of the water in the large jug.
- C. The temperature of the water in a small glass is two times lower than the temperature of the water in a large jug.
- D. The temperature of the water in the small glass is twice as high as the water temperature in the large jug.
- E. The temperature of the water in the small glass is the same as the temperature of the water in the large jug.

Reason:

- A. The temperature of hot water is inversely proportional to the amount of hot water

- B. The temperature of hot water is proportional to the amount of hot water.
- C. The temperature of hot water is not determined by the amount of hot water.
- D. The temperature of hot water is determined by the amount of hot water.
- E. The temperature of hot water is determined by the type of water container in which it is occupied

Are you sure about your answer?

1. Sure
2. Not sure

The results of student answers are then analyzed and grouped into four categories measured based on Table 1.

Table 1 Categories of grouping misconceptions

Tier 1	Tier 2	Tier 3	Category
Right	Right	Certain	Understand Concept
Right	Wrong	Certain	Misconception
Wrong	Right	Certain	Misconception
Wrong	Wrong	Certain	Misconception
Right	Right	Not sure	Guess
Right	Wrong	Not sure	Don't Understand Concept
Wrong	Right	Not sure	Don't Understand Concept
Wrong	Wrong	Not sure	Don't Understand Concept

(Arslan et al., 2012)

The result of student answers that have been grouped then calculated the percentage using the following equation:

$$P = \frac{f}{N} \times 100\%$$

Description:

P = Group percentage figures

f = Number of students in each group

N = Total number of students

(Sudjana, 2013)

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Classification of students' level of misconceptions is listed in Table 2.

Table 2 Classification of levels of misconception

Percentage	Category
0-30	Low
31-60	Currently
61-100	High

RESULT AND DISCUSSION

The results of student answers obtained are then averaged. The average percentage results can be seen in Figure 1.

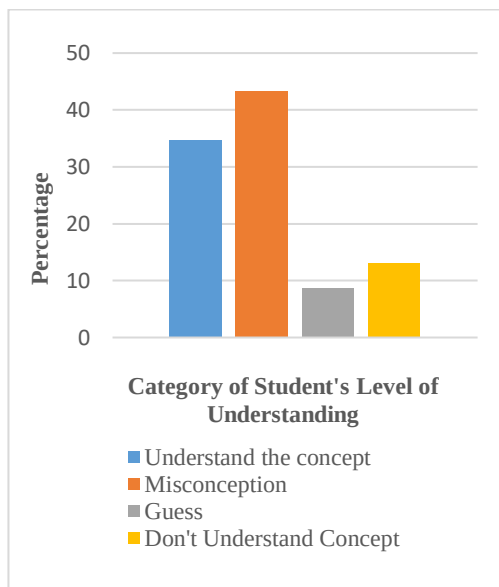


Figure 1 Percentage of students' understanding level

The percentage of misconceptions about high school and madrasah aliyah can be seen in Figure 2.

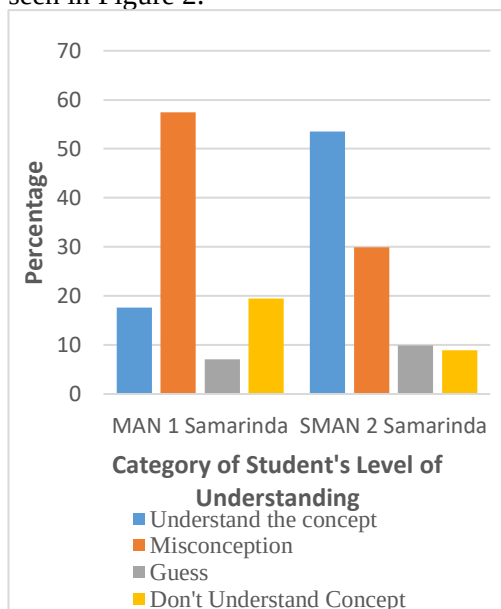


Figure 2 Percentage of misconceptions in senior high schools and madrasah aliyah

Figure 1 shows the results of each student's percentage level of understanding. This shows that the percentage of misconceptions in students is 43.4%. The percentage of understanding

concepts is 34.8%. The percentage is only guessing at 8.7%. The percentage that does not understand the concept is 13.1%. The percentage of misconceptions obtained for all concepts of temperature and heat is still in the moderate category.

The misconceptions that occur in each sub-material are as follows:

Explain the concept of temperature

The number of misconceptions experienced by students in explaining the concept of temperature occurs in the indicator of question number 3, with several misconceptions of 25% about the difference in temperature obtained on the ice block, which is divided into two parts. Students think that the temperature obtained by the two ice blocks will differ in temperature depending on their size. According to the law of zero thermodynamics, the correct concept is that when ice is cut into several pieces, the temperature will remain the same because of the thermal equilibrium between the three cubes of ice. This is because the object's temperature does not depend on the size, mass or substance, or material of the object. Lestari et al. (2015) also experienced The same misconception in their research that students considered the temperature of an object to be proportional to the object's mass. Students also experienced misconceptions on indicator question number 4, with several misconceptions of 62.5%. Most students are wrong in using the thermometer calibration equation, so many students are wrong in converting the Celsius scale to an arbitrary scale. Misconceptions were also found in the indicator of question number 6, with several misconceptions of 61.3%. Students assume that the size of an iceberg affects the temperature of the ice. The correct concept is that ice temperature is not determined by size, and ice is not always 0 °C. Another misconception is also found in the

indicator of question number 7, with several misconceptions of 51.3%, which is about the temperature limit that an object can achieve. Students think that -273 K is the lowest temperature limit that an object can reach. The correct concept is that the minimum temperature that objects can reach in nature is 0 kelvin .

Explain the concept of heat

The sub-material explains the concept of heat. One of the misconceptions is found in the indicator question, "Pay attention to the following statement!"

1. Density
2. Mass
3. Temperature
4. Form
5. Volume

If a liquid is heated to a temperature of 100°C , the factor that does not change is

- A. Density.
- B. Mass.
- C. Temperature.
- D. Form.
- E. Volume

Reason:

- A. The mass of an object will have a constant value, whether it is not receiving heat or receiving heat.
- B. Density will have a constant value, both in a state not receiving heat or receiving heat.
- C. The temperature will have a constant value, both in a state not receiving heat or receiving heat.
- D. The form will have a fixed value, both in a state of not receiving heat or receiving heat.
- E. The volume will have a fixed value, whether it is not receiving heat or receiving heat

Are you sure about your answer?

1. Sure
2. Not sure

The quantity of misconceptions obtained is 50%. Students argue that when a liquid is heated, the factor that does not change is mass. The correct concept is that when a liquid is heated, the factor that does

not change is the density because when a liquid is heated, what changes are mass, volume, shape, and temperature.

Thermal Equilibrium and Black's Principle

The finding of misconceptions occurs in the indicator of the question, "Mother saw Dayat take an Ice Cream that had been stored in the freezer for a day and night (freezer). Her mother thought her hands would freeze too if each Ice Cream didn't have a wooden stick as a handle; luckily the wooden stick wasn't as cold as ice. How do you respond to Ibu Dayat's opinion?"

- A. I agree with Ibu Dayat; a wooden stick feels warmer than ice.
- B. I disagree with Ibu Dayat; wooden sticks are colder than ice.
- C. I agree with Ibu Dayat; wooden sticks have a higher temperature than ice.
- D. I disagree with Ibu Dayat; a wooden stick has the same temperature as ice.
- E. I agree with Ibu Dayat; wooden sticks have a lower temperature than ice.

Reason:

- A. Objects that touch each other or unite in the same space for a long time do not necessarily have the same temperature, depending on the material.
- B. Objects that touch each other or unite in the same space for a long time have the same temperature, regardless of the material.
- C. Objects that touch each other or unite in the same space for a long time have the same heat and are largely determined by the object's material.
- D. Objects that touch each other or unite in the same space for a long time do not necessarily have the same heat and do not depend on the material.

- E. Objects that touch each other or stick together in the same space for a long time do not necessarily have the same temperature and do not depend on the material

Are you sure about your answer?

1. Sure
2. Not sure

with a percentage quantity of 42.5%. Students said that if a wooden stick is stuck in an ice cube even though it has been stored for a long time in the refrigerator, the wooden stick and the ice will have different temperatures because they have different constituent materials. The results of the same misconception research were found by Alwan (2011) and Chu et al. (2012). The correct concept is that when objects are stored in the same place for some time, the temperature of the two objects will remain the same even though the two materials are different.

Another misconception found is in the indicator of the question, "Dina took the eggs that were still warm from the pot into a container without a lid and then placed it on the table. A few minutes later, the eggs cooled. Why do you think this could happen?"

- A. Warm eggs will naturally cool.
- B. Warm eggs tend to absorb the cold in the environment quickly.
- C. Warm eggs radiate heat to the environment.
- D. Warm eggs radiate heat to the surroundings.
- E. Warm eggs radiate cold from the environment

Reason:

- A. A warm object will naturally release its heat to an environment with a lower temperature.
- B. Warm objects will naturally absorb cold from an environment with a lower temperature.
- C. A warm object radiates its high temperature to an environment with a lower temperature.

- D. A warm object will radiate heat to an environment with a lower temperature.

- E. A warm object will release its heat to the environment because it has a higher temperature.

Are you sure about your answer?

1. Sure
2. Not sure

with several misconceptions of 32.5%. Students think that warm eggs left in the open will naturally cool down. Students also think that warm eggs tend to absorb cold from the environment quickly. The correct concept is that if an object in the environment has a different temperature from the ambient temperature, the object's temperature will adjust to the ambient temperature because of the concept of thermal equilibrium between the two. This is by the misconceptions experienced by students, students can explain that equilibrium can occur in objects that are in contact with each other, but students ignore the concept that without physical contact, both objects can experience thermal equilibrium (Witanecahaya & Jatmiko, 2014).

The effect of heat on changes in temperature

The misconceptions are found in the indicator of question number 17, with several misconceptions of 32.5%. Students argue that an increase in the energy of a particle does not affect an increase in the temperature of the particle. Students assume that the heat felt on an object after the object is used solely occurs due to an increase in the object's temperature. The correct concept is that an increase in the temperature of a particle is due to an increase in the particle's energy.

Changes in the shape of an object due to heat

The misconceptions are found in indicator question number 22, with

several misconceptions of 58.8%. Students assume that if an object continuously receives heat, the object's temperature will increase to the boiling point of the object, and there will be no increase in temperature and no change in form. Students also assume that when the temperature of the object has increased to the boiling point/melting point, the object's temperature will slowly decrease and be accompanied by changes in the object's shape. Alfiani (2015) also found this concept error in his research that students know heat is needed in changing the shape of objects, but students do not know that during the process of changing form, heat does not cause temperature changes. Maunah & Wasis (2014) also experienced the same thing in their research, which stated that students assume that a temperature change is followed when there is a change in form. The correct concept is that if an object continuously receives heat, the object's temperature will increase to the boiling point/melting point of the object. The temperature becomes constant, and changes occur in the object's shape.

Factors affecting heat transfer

Another misconception finding is found in the indicator question number 27 with several misconceptions of 50%. Students assume that heat transfer is not affected by air pressure. According to students, there is no difference in the temperature of boiling water vapour in the highlands and the lowlands. The cause of the difference that occurs is only in the length of time the water is heated. Students think that boiling water in the highlands takes a faster time than in the lowlands. This misconception finding was also found by Amalia *et al.* (2016). The correct concept is that there is a difference in the boiling point of water between high land and low land because it is influenced by air pressure. The misconceptions are found in the indicator of question number 29, with several misconceptions of 62.5%. Students assume that the specific heat possessed by an

object does not affect the cause of objects to become hot or cold more quickly. Similar Misconceptions were also found by Hafizah *et al.* (2014), where students considered the higher the specific heat, the easier the object to rise in temperature. The correct concept is that specific heat is very influential on heat transfer, where a small specific heat can make it easier to absorb and release heat.

Expansion

The misconceptions are found in the indicator of question number 19 with several misconceptions of 51.3%, which is about objects with different coefficients of expansion. Students argue that when the object is heated, the increase in the object's length is not affected by the coefficient of expansion. Students also think that the expansion coefficient is proportional to the square of the increase in length. The correct concept is that the increase in the object's length is proportional to the coefficient of expansion of the length of the object. Thus the coefficient of expansion of an object is very influential on the increase in length of an object.

Heat transfer by conduction

The misconceptions are found in the indicator of question number 32, with several misconceptions of 51.3%. Students think that it would be better to use a sweater made of wool in winter because wool can keep the cold outside the body. The correct concept is that the wool fabric used is a good insulator to inhibit the transfer of heat from the body to reduce body heat loss.

Heat transfer by convection

The misconceptions are found in the indicator of question number 40 with a misconception quantity of 38.8%, which is about the heat transfer that occurs when mixing water with

different temperatures. Students do not understand the concept of heat transfer by convection, so they are wrong in applying the concept. The correct concept is that when the water of different temperatures is mixed together, heat transfer occurs by convection, i.e. heat transfer is accompanied by an intermediate substance.

Radiation heat transfer

The misconceptions are found in the indicator of question number 42, with several misconceptions of 32.5%. Students misunderstand the concept of heat transfer that occurs by radiation. Students assume heat transfer from the sun can occur naturally, and students ignore the concept of radiation heat transfer that accompanies the process.

The finding of misconceptions from the interpretation of the results of the three-tier diagnostic test in terms of temperature and heat sub-materials can be seen that the most misconceptions experienced by students in the sub-material confirm the concept of temperature and sub-material factors that affect heat transfer with each percentage of misconceptions of 62.5% and into the high category.

Misconceptions experienced by students can occur due to several factors, including teachers, friends, books, and themselves. This revealed misconception can be a record for teachers in learning, especially on the concepts of temperature and heat. Knowing the location of students' misconceptions will make it easier for teachers to carry out remediation learning (improvement). It is very important in learning if teachers always question students about the ideas and concepts they know. Teachers in teaching need to provide opportunities for each student to express the ideas and concepts known about the physics material they are studying. From that expression, the teachers will understand the misconceptions brought or owned by the students so that the teacher can

immediately correct the inequality that occurs in the conceptions that students have.

CONCLUSION

Based on the study results, it was concluded that students experienced misconceptions about the material of temperature and heat. Overall the percentage of misconceptions experienced by students is 43.4%, with the category of misconceptions belonging to the medium category. Based on the results of the misconceptions obtained, learning physics on temperature and heat needs to pay attention to students' understanding of each sub-material, especially the sub-material that emphasizes the concept of temperature, explains the concept of heat, analyzes thermal equilibrium events in the application of Black's principle, the effect of heat on temperature changes, finds factors that affect heat transfer (air pressure and specific heat) and applies the concept of heat transfer by conduction, convection, and radiation in daily life.

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