Four-Tier Diagnostic Test Assisted Website for Identifies Misconceptions Heat and Temperature

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Abstract

Misconceptions get special attention in educational research because they are inhibiting students in learning. Misconceptions often occur in learning physics, especially the concept of heat, and nearly every sub-concept of physics on students experience various misconceptions. One of them is defining heat. Many students believe that temperature is considered as a unit of measure for the amount of heat. This is a wrong conception. Thus, it needs to be identified using appropriate diagnostic test instruments to reduce students' misconceptions. Four-tier diagnostic tests can detect students' misconceptions because they can dig deeper into understanding students' conceptions. Unfortunately, the diagnostic tests of student misconception are still rarely applied at most schools. The reason is time constraints in the implementation and correction of the diagnostic tests. Therefore, here we report digital four-tier diagnostic test instruments of student misconception on heat and temperature through a helpful website and can be accessed anywhere.

Keywords: digital, four-tier test, heat and temperature, misconception, website

INTRODUCTION

The concept is a general description with meaning, characteristic, or a certain resemblance grouped to present an object or event to be understood. A concept is an internal group of stimulus presentation, which can not be observed due to be concluded by the behavior (Dahar 2011). Each student has diverse capabilities in constructing knowledge and understanding of the concept. This gives rise to differences in interpretations of the same phenomenon. Errors or imperfections in interpreting the idea of cause misconceptions. Misconceptions or wrong concepts refer to a concept incompatible with the scientific sense or understanding of the experts in that field (Suparno 2005). The misconception is a matter that needs to be reduced because if there are still exist, it will make students mistaken in studying the following material (Suliyanah 2018).

Heat is very closely related to life. Heat is not the energy possessed by an object but rather refers to the amount of energy transferred from one thing to another at different temperatures (Giancoli 2001). But students had misconceptions about the purpose of defining the temperature by assuming the temperature as a unit of a measure for the amount of heat.Indeed, they have a wrong conception of heat and temperature. Students should understand the concept of heat precisely to each phenomenon and concepts related to heat (Giancoli 2001). The concept of temperature is also abstract because it cannot be seen directly by the shape of the temperature but can only be felt, measured, and the amount of temperature changed is calculated (Irawati 2018).

Studying the concept of heat and temperature is among the basis for studying the theory and application of thermodynamics. An understanding of the concept of heat that moves due to temperature differences and is caused by the difference in kinetic energy of the particle motion becomes a key that heat is energy transferred. Energy can be transformed from one form to another energy (principle of conservation of energy), both natural and engineered technology. The first law of thermodynamics is a statement of the law of energy conservation (Giancoli 2001).

Understanding the concept of entropy studied in thermodynamics and the basic principles of energy equipartition in ideal gases are also very helpful in understanding the determination of the α and β parameters in the Maxwell-Boltzmann distribution function Statistical Physics. We know that statistical physics also recognizes the study of bosons and fermionic particles, which is also helpful for studying the Heisenberg uncertainty principle in quantum physics. Related students' understanding of these concepts is among the key to understanding a wide range of other scientific concepts (Sozbilir 2015). Therefore, we need a diagnostic test on the concept of heat and temperature to avoid misconceptions to be given the appropriate treatment (Arikunto 2006) and to identify student misconceptions on physics material, a specific test instrument is needed (Tumanggor 2020).

Various diagnostic instruments have been widely used to identify misconceptions (Halim et al. 2020), such as interviews, open-ended questions, concept maps, and multiple-choice tests, which each has advantages and disadvantages in its use (Gurel et al. 2015). Interviews provide an opportunity to investigate in-depth and flexibly, but it requires time and effort to achieve large samples and analyze the results. Multiple choice test to overcome the problem mentioned above in the interview, but unable to investigate misunderstandings in-depth and to detect guessed answers effectively (Kaltakci 2012). The limitations that occur in the form of multiple encourage researchers to create a more effective test to identify misconceptions that aim to improve various choice limitations, that is, two-tier, three-tier, and four-tier (Gurel et al. 2015, Kiray & Simsek 2020).

Diagnostic tests two-tier and three-tier address the problem of detection of misconceptions than multiple-choice test. However, the development of instruments two-tier test still has the disadvantage of not ascertaining the cause of students who experienced the misconceptions (Gurel et al. 2015). The two-tier test has too high (overestimate) outcomes in identifying misconceptions, for all the wrong answers are considered misconceptions (Kutluay 2005). Weakness in the two-tier instrument test then improved with the presence of a diagnostic test form the three-tier test. The three-tier test comes with the added level of confidence placed after the first two levels to ensure confidence in the students to answer questions in the two previous levels (Gurel et al. 2015). However, it still has limitations in terms of confidence levels for tiers 1 and 2. The level of confidence comes after the first two levels. When students fill in the between level, they were unsure of the answer they chose, but they would not want to select a sure because there is only one level of confidence on the matter. For this reason, the four-tier test present added two confidence levels is to tier questions and tier reason. The four tier misconception diagnostic test instrument was stated to be more knowledgeable about students' understanding conditions (Kaltakci 2012).

Implementation of tests generally shaped paper-based tests. Diagnostic tests are still using paper, certainly less practical in use. Because of lots of paper consumed and the amount of time required for the process, it leads to using the digital-based test—one of the alternatives that can be done to overcome these problems, taking advantage of emerging technologies. Technology can support almost every aspect of assessment somehow - from administering individual tests and assignments to assessing assessment across a school, faculty, or institution (Nikolova, M 2011). Namely replacing based exams paper to form non-paper exam (paperless) assisted website. Students can access the website on various device (Pratama 2020), personal computers (PC), or gadgets such as smartphones, tablets, or any other proper electronic devices connected to the internet with browser Google Chrome, Mozilla Firefox, Internet Explorer, Safari, Opera, and so on. Of course, this application has several advantages: increasing the efficiency of the assessment, flexible in some times and places, giving direct feedback, and reducing errors in the assessment process (Huseyin and Ozturan 2018).

METHODS

The method used is the descriptive quantitative method. Four-tier test instrument as many as 26 questions tested on 50 students of class XI of public school Sekolah Menengah Atas Negeri (SMAN) 5 Depok who have received the material heat and temperature. This instrument is based on the stages of manufacture of the research conducted by Caleon & Subramaniam. Sampling using Disproportion stratified random sampling is a technique used to determine the number of stratified samples of the population but disproportionately from each stratum (Sugiyono 2015). The strata, which meant that a population of 226 students was grouped into groups of the high, medium, and lower than the value obtained by students at the midterm exam subjects of Physics in the first half. Stages of research begin with a diagnostic test instruments four-tier test, expert judgment by the test instrument, testing instrument to test several students of non-samples, making the instrument test four-tier into digital form website, expert review by the media, taking the data, processing and analyzing data, and concluding.

The indicators of each question are shown in TABLE 1.

TABLE 1. The indicators of each question

No	Problem Indicators	Question Number
1	Revealing the definition of temperature	1
2	Comparing the temperature of a particular object	2
3	Stating the basic unit of temperature	3
4	Determining the boiling point of water	4
5	Writing down the temperature on the Celcius to Kelvin scale	5
6	Applying the relationship between the Celsius scale to the Fahrenheit scale	6
7	Using the thermometer calibration equation on the Celsius scale with any scale	7
8	Identifying the expansion of solids	8
9	Analyzing the coefficient of expansion length of various types of metal	9
10	Defining heat	10
11	Mentioning the characteristics of the heat change process	11
12	Comparing an object that receives heat	12
13	Identify events due to the influence of heat	13
14	Identify the process of absorbing heat	14
15	Comparing the temperature rise according to the specific heat of the substance	15
16	Identify changes in the form of a substance to evaporate and boil	16
17	Describing the process of changing the form of a substance	17
18	Giving an example of the process of changing form which releases heat	18
19	Calculating the heat from the substance change event	19
20	Using the heat equation to find the final temperature of the mixture	20
21	Identifying heat due to temperature changes when in contact	21
22	Differentiating heat transfer by conduction, convection, and radiation	22
23	Identifying the heat transfer by conduction	23
24	Identifying transfer of heat by convection in life everyday	24
25	Identifying transfer of heat by convection naturally	25
26	Identifying transfer of heat by radiation	26

Data from the students' answers are grouped based on the assessment criteria form four-tier test developed by Kaltakkci (Kaltakkci 2015), as shown in TABLE 2.

TABLE 2. Criteria Answer Four Tier Test based Kaltakkci Gurel

Category	The Combination of The Answer			
	Options (Tier I)	The Level Of Confidence (Tier II)	Reason (Tier III)	The Level Of Confidence (Tier IV)
Understand	Correct	Sure	Correct	Sure
Understood Partially	Correct	Sure	Correct	Not Sure
	Correct	Not Sure	Correct	Sure
	Correct	Not Sure	Correct	Not Sure
	Correct	Sure	False	Sure
	Correct	Sure	False	Not Sure
	Correct	Not Sure	False	Sure
	Correct	Not Sure	False	Not Sure
	False	Sure	Correct	Sure
	False	Sure	Correct	Not Sure
	False	Not Sure	Correct	Sure
	False	Not Sure	Correct	Not Sure
Misconceptions	False	Sure	False	Sure
Do Not Understand Concept	False	Sure	False	Not Sure
	False	Not Sure	False	Sure
	False	Not Sure	False	Not Sure
	False	**Not Sure**	**False**	**Not Sure**

The percentage of students are grouped into categories to understand the concepts, understand the majority, do not understand the concept, and misconceptions which are calculated by the formula (Sudijono 2009), as follows:

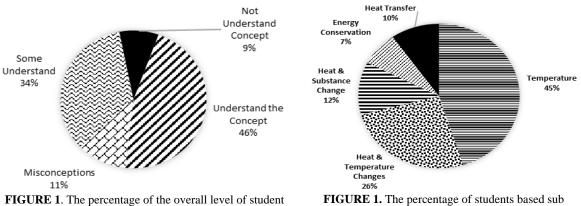$$p = \frac{f}{N} \times 100\%$$

(1)

p = the percentage figure, f = the number of students per group of each problem, and N = the number of students as research subjects. Results of the calculations then grouped (Sudijono 2009) as follows:

TABLE 3. Criteria Misconceptions By Percentage

Criteria	Percentage
High	61% - 100%
Moderate	31% - 60%
Low	0% - 30%

RESULTS AND DISCUSSION

The research result is then processed and obtained some profiles that describe the misconceptions that occur, namely: 1) Data percentage of the overall level of student understanding; 2) Data on the percentage of students misconceptions subconcepts heat and temperature; 3) Data misconceptions percentage of students in each group were high, medium, and low.

FIGURE 1. The percentage of the overall level of student understanding heat and temperature concept

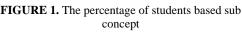**FIGURE 1.** The percentage of students based sub concept

FIGURE 1 shows the categories of understanding the heat and temperature concept, which is understanding concept shows the highest position with 46%. Percentage category misconception is in the following position that is equal to 11%, partially understood by 34%, and the lowest in the data did not understand the concept of 9%. Sub concepts that have the highest percentage of misconceptions are shown in FIGURE 2 of the subconcept of temperature by 45%, while the lowest is sub concept of energy conservation by 7%. The highest misconceptions that occur in the sub-concept of temperature are the temperature indicators reveal a re-definition by 76%, while the misconceptions that arise in the sub-concept of energy conservation are identifying heat indicators due to changes in temperature on contact by 16%. We replace the Black Principle with the energy conservation principle. The use of the term "Black Principle" in different books and equivalent high school physics textbooks written by Marten Kanginan, Ketut Kamajaya, and Karyono is inappropriate. Because several major textbooks in College Physics written by Giancoli C. Douglas, Halliday & Resnick, and Serway-Jewett do not mention the "Black Principle", energy conservation $(Q_{in} - Q_{out})$.
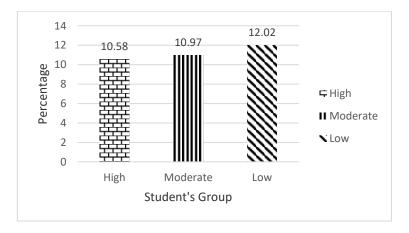

FIGURE 2. Percentage of students by groups of student

FIGURE 3 describes the most common misconceptions in the low group with an average percentage of misconceptions of 12.02%, followed by the group was at 10.97%, and the least experienced misconception that higher group by 10.58%.
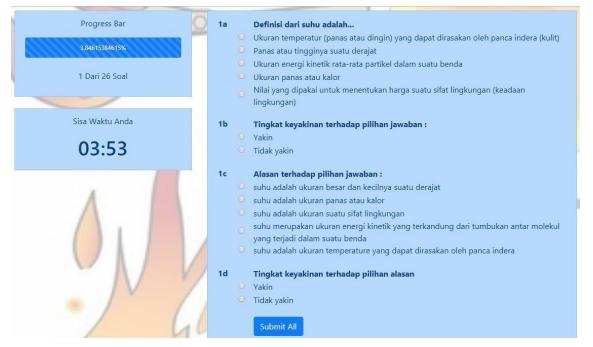
FIGURE 3. Printscreen Question 1

The students misunderstand the purpose of defining temperature by considering temperature as a unit of measure for the amount of heat of 76%. This could be following the research results for elementary school students aged 9-10 years, where they think understanding temperature and heat is tricky because of its abstract nature (Yeo et al. 2021). But exceptionally because this is consistent with what was previously found by Kesidou and Money in their research: the average student aged between 15-16 years assumes that temperature is the sum of the number of heats (Sozbilir 2003). Temperature (in Kelvin) measures the average kinetic energy of the molecules individually (Giancoli 2001). The faster the molecules of an object move, the higher the object's temperature (Duncan 2014).

Furthermore, in identifying heat due to temperature changes when objects are touched, a misconception occurs because some students are still mistaken. After all, heat will flow instantaneously from hot to cold, even though the center of gravity is in the presence of a temperature difference. Meanwhile, when one end of the object is heated, the molecules move faster and cause collide with the neighboring molecules to move more slowly. They then transferred some of the energy of thermal motion by molecular collisions and the object (Giancoli 2001).

On the matter of indicators specifies a principal temperature amount, 62% of students have understood. However, as much as 38% of students mistakenly believe the reason why Kelvin used as a unit of the principal amount due to the temperature inside the SI unit is regarded as units of degrees Kelvin temperatures are easily understood and used in everyday life. Kelvin serves a unit temperature principal amount for a unit degree temperature more stable compared with another temperature scale. Absolute zero is the basis for the temperature scale known as the full scale or Kelvin and is widely used in science (Giancoli 2001).

Furthermore, in identifying the phase transition evaporate and boil, as much as 82% of students know that when the water is boiling and then heated continuously, the water temperature condition remains. However, the reason given is not quite right considering the boiling point of the highest owned by the water is equal to 100 °C when 100 °C been achieved, the temperature returns to remain constant while heat is added to transform liquid water into vapor (Sozbilir 2003). Heat received no water to raise the temperature but is used to turn liquid into vapor form.

Regarding the indicators of heat transfer by convection, most students have understood that the land breeze is an example of natural convection. At noon, the temperature on the mainland rose faster than sea temperature (for the specific heat capacity of the soil is much smaller). Hot air over the land rises and is replaced by colder air from the sea. Instead, at night, the ocean loses more heat and cools more slowly. The air over warmer sea than on land, and the breeze blowing from the land to the ocean (Duncan 2014).

Then the diagnostic test using this website can run on multiple platforms, PC or smartphone with a variety of browsers including Google Chrome, Mozilla Firefox, Internet Explorer, Safari, Opera, and others, making it able to facilitate the students to be able to be used anywhere and anytime. The website can present images and text (allows additional audio and video) and can be used to add visualization for students. The added value obtained when compared with the results of similar studies (such as the use Google Form), i.e., when it occurs lag (error), the website can save the previous page, so it does not need to fill in from the beginning, and then design interface/pages can be created as needed and can be accessed using a PC or smartphone.

CONCLUSION

Misconceptions of students on the concepts of heat and temperature have been identified well. We obtained that students do not understand the relationship between heat and temperature with energy because they understand that heat refers to a hot extent only. Diagnostic tests Four-Tier Digital Test (4TDT) can optimize the process of assessing digital technology and the innovation of media evaluation.

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