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Probing 8th Grade Students' Conception about Heat and Temperature Using Three-Tier Test : A Case Study

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Abstract

The aim of this study is to investigate the various categories of students' conceptions about heat and temperature, so that the misconceptions that students may have can be prevented and regenerated as early as possible.The subjects of this study were 203 8th grader students in one of the Junior High Schools in Mempawah District, West Kalimantan. Data was collected using a three-tier test developed by Kusumah (2013), questionnaire and interview.The data were analyzed and categorized based on their configuration of the answer, the reasons and confident rating index. Result showed that there are four main categories of students' conceptions:understand the concepts;lack of knowledge; misconceptions; and error. In addition, students also still have 18 kinds of misconceptions about the heat and the temperature despite the material was studied in their 7th grade. Therefore the results of this study can be used as a basis for teachers so that learning process does not only focus on delivering material, but also improves students' conceptions.

Key words: Conception, Heat and temperature, Misconceptions

INTRODUCTION

In learning process at school, students usually bring many thoughts about scientific phenomena which sometimes do not fit with the scientific view when they enter the class. The initial conception of students is often referred as preconception (Pujianto, 2013; Kambouri, 2015). Ibrahim (2012) states that a preconception is usually easier to change. The preconception will change when the student is taught the real concept, this is called alternative conception or misconception. Many studies states that alternative conception occur at all levels of education such as primary schools (Beerenwinkel et al., 2011; Hobson et al., 2010), junior high schools (Çaliket al., 2010; Potvin et al., 2012; Sadler & Sonnert., 2016; Schnborn et al, 2014; Yoanita&Akhlis, 2015), high school (Lombardi et al., 2013; Lee &Byun, 2012; Cetingul&Geban, 2011), and even on college (Alwan, 2011; Fitzallen et al., 2016; Kartal et al., 2011; Nasrudin&Azizah, 2020).

This alternative conception or misconception is different from a lack of knowledge or lack of concept. Where the lack of concepts can be improved by continuous learning. The concept of misconception is trusted, and unconsciously students can inhibit appropriate acceptance and integration of new concepts or skills (Hasan et al., 1999).Suparno (2005) states that misconception is a concept that is not in accordance with the recognized concept by experts. Misconceptions can take the form of initial concepts (preconceptions), incorrect relationships between concepts, intuitive ideas or wrong views. Hughes, et al (2013) states that these misconceptions are argued to pose a challenge to educators for three reasons: 1) misconceptions are appear to be highly resistant to extinction, with standard instructtional strategies, 2) it could impact negatively on the learning of new information, and 3) a tendency to affirm misconceptions may signal the need for additional critical thinking training.

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Science education research has identified a broad range of challenges in learning science. There are often many misconceptions that occur in students in learning science, one of which is the concept of heat and temperature. Schönborn, et al (2014) found that students often hold two conceptions in relation to heat that are not entirely in line with the scientific view: that our sense of touch is a good thermometer; and that metal is inherently cold. Temperature is seen as a measure of how hot (or cold) objects are. Students equate just the meaning of temperature with heat or hot.

The concepts related to temperature and heat are important at an introductory level, because it underpins physics and chemistry (Tanahoung et al., 2010). Its also very common in science curricula at all levels of elementary, secondary and tertiary schools (Gönen&Kocakaya, 2010). Though the heat concept learned in elementary and secondary schools will become students' basic knowledge in learning other concepts related to heat in high school and college, for example thermochemical, thermo-dynamic, mechanical, wave, etc. Therefore it is necessary to identify students' conceptions of temperature and heat material, so that the miscon-ceptions that students may have can be identified and prevented as early as possible. Because the occurrence of weakness in understanding ongoing concepts, will make difficulties for students to accept material in higer educations (Gönen & Kocakaya, 2010; Yoanita & Akhlis, 2015).

Among several methods in diagnosing misconceptions, interviews have a significant role because researchers may get detailed information about students' cognitive knowledge structures (Soeharto, et al., 2019). Gurel, et al., (2015) states that 53% among their 273 studies are using interview as diagnostic tools. As done by Jankvist & Niss (2018) where "maths counselors" using interview to detect students who has difficulties in learning, to diagnose the nature of their difficulties, and to design interventions meant to assist the students in counteracting them. But, Gurel et al., (2015) states that although interview strategies have the advantages such as gaining in-depth information and flexibility, a large amount of time is required to interview a large number of people in order to obtain greater generalizability. Also training in interviewing is required for the researcher. In addition, interviewer bias may taint the findings.

To overcome the limitations of interview, researchers using open ended question to diagnose misconception (Alfiani, 2015; Alias& Ibrahim, 2016; Celik, 2016; Fitriah, 2017;). However Soeharto, et al., (2019) states that open ended questions also has some drawbacks such as difficulties in interpreting and analyzing student answers, requiring specialized skills for getting meaningful answers, some response answers may not be useful, bias answers may occur if students do not understand the topic of the question.

Multiple choice test also kwon widely as a diagnostic tools. Gurel, et al., (2015) sums up some of the advantages of multiple-choice tests are: (1) They permit coverage of a wide range of topics in a relatively short time. (2) They are versatile, and can be used to measure different levels of learning and cognitive skills. (3) They are objective in terms of scoring and therefore more reliable. (4) They are easily and quickly scored. (5) They are good for students who know their subject matter but are poor writers. (6)They are suitable for item analysis by which various attributes can be determined. (7) They provide valuable diagnostic information and are viable alternatives to interviews and other qualitative tools in gauging students' understanding and in determining the prevalence and distribution of misconceptions across a population. However, multiple-choice tests do not provide reasons for students' holding a particular conception (Kirbulut & Geban, 2014). A student can give a correct answer with a wrong reason or a wrong answer with a correct reason.

Because of limitation above, researchers start using two-tier test. To sum up, two-tier tests have benefits compared to simple multiple-choice tests, interviews, and open-ended tests. This test provides an answer option for multiplying student reasoning or interpretation toward the question of misconception in science (Soeharto, et al., 2019). Although a two-tier test eliminates the above-mentioned drawback of a conventional multiplechoice test, it has a limitation: It cannot differentiate misconceptions from lack of know-ledge (Kirbulut & Geban, 2014)

To overcome the limitation in two-tier test, researcher developing three tier test. Where first, student are faced to simple multiple choice, then they are asked to choose the reasons of the given answer for the first tier, and last, they have to answer their confidence rate for the first two tiers. Three-tier tests are considered more accurate in identifying students' misconceptions. The three-tier test can detect students' lack of understanding by using a level of confidence in the answers given by students, and this condition helps researchers get a more accurate percentage of misconceptions as each student needs different treatments to correct their misconceptions (Soeharto, et al., 2019). The aim of this study is to investigate the various

categories of students' conceptions about heat and temperature, so three-tier test were used accompanied with questionnaire and interview.

METHOD

This study was a qualitative research with case study type. The study was conducted in one of the Public Junior High Schools in Mempawah Regency, West Kalimantan. This study involved all 8th grade students consisting of 208 students, but in the implementation there were 5 students who could not take part in the research activities so that the subjects in in this study only consisted of 203 students. All of these students have studied the heat and temperature material in their 2nd semester of 7th grade.

Data on students' conceptions were obtained through diagnostic tests using 10 questions that were chosen which were considered to be the most representative to explore students' misconceptions in heat and temperature developed by Kusumah (2013) regarding heat and temperature material. This test has been validated logically by experts and empirically by doing field trial in her research. The items used are three-tier test with multiple choice with closed reasons and accompanied by a scale of confidence rating index.

In addition, in this study also used questionnaires and unstructured interviews. Questionnaires are used to collect supporting data in the form of data on student interest and motivation in learning heat and temperature. While interviews are conducted on students and teachers to explore the causes of errors or misconceptions that occur in students. Interviews were conducted by taking a random sample of several students who had worked on the three-tier test.

The results of students' answers in three-tier tests are differentiated according to their categories. The assessment of students' conception is based on a combination of students' answers using the analysis techniques carried out in Kusumah's (2013) research. This analysis technique is based on a combination of student answers to the two-tier test and the scale of the confidence rating. It showed in Table 1.

Table 1. Analysis Technique

Category	Answering type combination
Understanding the concept	Correct answer, correct reasoning, CRI ≥4
Error	Wrong answer, correct reasoning, CRI ≥4
	Correct answer, wrong reasoning, CRI ≥4 (unrelated answer and reasoning)
	Wrong answer, wrong reasoning, CRI ≥4 (unrelated answer and reasoning)
Lack of Knowledge	Correct answer, correct reasoning, CRI ≤3
	Correct answer, wrong reasoning, CRI ≤3
	Wrong answer, correct reasoning, CRI ≤3
	Wrong answer, wrong reasoning, CRI ≤3
	Correct answer, wrong reasoning, CRI ≤ 3 (unrelated answer and reasoning)
	Wrong answer, wrong reasoning, CRI ≤3 (unrelated answer and reasoning)
Misconception	Correct answer, wrong reasoning, CRI ≥4
	Wrong answer, wrong reasoning, CRI ≥4

Kusumah (2013)

To make it easier to process data, each answer category is given a code that shows the abbreviation of that category. While misconceptions statment used as distractors matter sorted first. The statement of misconception in the there-tier test used is a total of 18 statements, so the points in this type code then filled in with the serial number of the misconceptions presented from M - 1 to M-18. The misconceptions in the diagnosis instruments are listed in Table 2.

Table 2. The misconceptions in the diagnosis instruments

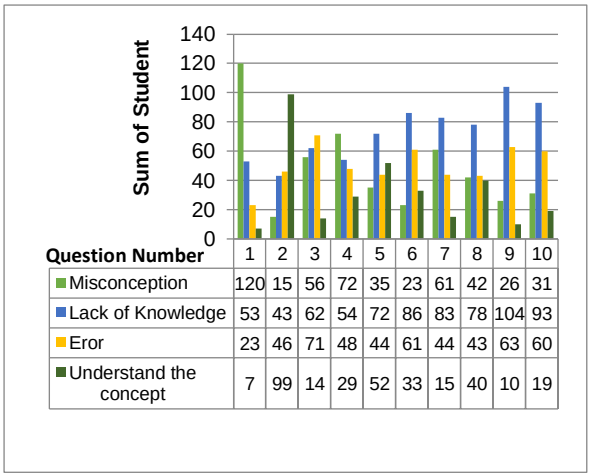
Indicators	Students misconceptions	Number items
Explain the differences about heat and temperature	temperature is a measure of the amount of heat, where objects with the same temperature then the same amount of heat. (M-1)	1
	substances can have a certain amount of heat in them. (M-2)	1, 2
	cold objects does not contain heat. (M-4)	2
Conclude that heat transfer occurs due to temperature differences	the heat is hot, while the temperature can be cold or hot. (M-3)	3
	there are two types of heat, heat and cold heat. (M-5)	3
	heat is drawn by cold objects so that heat and cold become neutral. (M-6)	3, 4
	temperature can be transferred.(M-7)	3, 4
	cold objects does not contain heat. (M-4)	4
Explain the quantities that affect the rise of temperature	if the final temperature is higher, the more heat the object needs to increase its temperature. (M-8)	5
	heat is influenced by the volume of objects. (M-9)	5
	heat into objects with different levels of ease.(M-10)	5, 6
	heat is only influenced by the mass of the object. (M-11)	6
	different objects, pulling heat in different ways. (M-12)	6
Explain the effect of heat on changes in the objects form	cold objects does not contain heat. (M-4)	7
	heat is drawn by cold objects so that heat and cold become neutral. (M-6)	7
	air can cool objects when the object is surrounded by air. (M-13)	7, 8
	metals have the ability to attract, hold, strengthen or absorb heat and cold. (M-14)	8
	boiling point is the highest temperature that a substance can reach. (M-15)	8
Illustrates the relationship of time to the temperature of an object when it changes shape in graph	boiling point is the highest temperature that a substance can reach. (M-15)	9
	temperature changes as long as the substance changes form. (M-16)	9
	water cannot be 0^{o}C. (M-17)	10
	the ice temperature is always $0\ ^{o}$ C or cannot be lower than $0\ ^{o}$ C. (M-18)	10

Data from interviews were analyzed by changing the results of interviews in the form of oral to written, then analyzing the answers and connecting students' answers with data from the questionnaire and from the results of written tests.

RESULT AND DISCUSSION

In this study, all the 8^{th} grader students were tested by three-tier test to diagnose theor conception. The results of the analysis and coding based on a combination of answers and reasons and the level of confidence of students in the three-tier test showed four main categories of student conception on temperature and heat

material, namely understand the concept, lack of knowledge, error and misconception The profile of students' answers from the four student conception categories is presented in Figure 1.



Question Number	1	2	3	4	5	6	7	8	9	10
Misconception	120	15	56	72	35	23	61	42	26	31
Lack of Knowledge	53	43	62	54	72	86	83	78	104	93
Eror	23	46	71	48	44	61	44	43	63	60
Understand the concept	7	99	14	29	52	33	15	40	10	19

Figure 1. Profile of students' conceptions.

On average 48 students included in the category of misconception, 73 students in the lack of knowledges category, 50 students in the error category, and 32 students in the understand the concept category. These results show that most students were categorized into the lack of knowledges and misconception.The results of this study in accordance with previous findings that students still lack of understanding and have misconception in heat an temperature concept (Gönen&Kocakaya, 2010; Irsyad, et al,. 2018; Suliyanah, et al., 2018).

Many students could give the correct answer, but they cannot give the right answer for the reason. Alwan (2010) states that this kind of situation shows that students could make sense with the concrete situation, closely with their life experiences, but they could not link what they had learned in physics classrooms with their experiences.

The form of the question that is used, followed with closed reasons that can allow students to choose unrelated answers. This kind of answers then can be divided into two additional categories, namely lack of knowledge, if the confidence rating scale ≤ 3; and the error category if the scale is a confidence rating of ≥4. This unrelated answer indicates existence element of guessing, or lack of interest, student attention or student understanding of how to do the problem (Kusumah, 2013).

So when students choose the wrong answer, it is not always caused by not understanding the concept or misconception, but it can also be caused by a lack of knowledge or the difficulty of students in answering questions because they don't understand the form of the questions given. These results are indicated by the results of interviews with students, which they admitted that they were confused when working on the questions given because of the form they had encountered for the first time. They only usually do an essay or multiple choice questions. The most important difficulty is when students are asked to answer how confident their answers are, because they tend to hesitate in determining the value of the confidence rating index This is what then affects students' conception categories from the results of the three-tier test answer analysis.

Question : Do you have difficulty working on the questions given?

Student 1 : No, just a little doubt in the level of confidence

Student 2 : The problem is difficult, because I've forgotten the material in 7th grade. It's been too long, it's forgotten

Student 3 : I am confused, because it was the first time working on a problem like this. Usually an ordinary essay or multiple choice

Student 4 : I am confused, because I have to choose a reason and how confident I am with the answer

Student's incomprehension in completing the three-tier test form that causes a large number of students belonging to the error category. The high error value also indicates the low interest and motivation of students in learning science. Based on the results of the questionnaire, 73% of students consider that science is a difficult lesson. This assumption often causes students to be

wrong in solving questions about heat and temperature (Rosita, 2011)

From the interviews, students found that they tend to have difficulty in learning science because the concepts are abstract and there are many concepts that must be learned. The learning process which doesn't connect the science concepts with events that occur in the daily life environment is also one of the factors causing low motivation of students in learning science. These result are in accordance with many studies (Albab, et al., 2020; Haqiqi, 2018; Fitriah, 2017; Arief, et al., 2012) that found students' low motivation can cause a learning difficulties.

From Figure 1 also seen that 23% of students who have misconceptions heat and temperature, whereas all students have learned the concepts of heat and temperature in the 2nd semester of 7th grade. This proves the theory that misconceptions can occur after learning (Suparno, 2005; Berg, 1991). Misconceptions after learning arise because students' low abilty in applying what has been studied in new problem (Fitriah, 2017).

The variety of student misconceptions that can be extracted from the three-tier test problem can be seen in Table 3.

Table 3. Variety of students' misconceptions

Scientific concept	Misconceptions that can be explored	Total
Heat is energy that moves so that an object cannot contain heat	Temperature is a measure of the amount of heat (M-1).	9
	Substances can have a number of heat (M-2).	1
Heat is energy that moves and can cause changes in temperature	Temperature is a measure of the amount of heat (M-1).	0
	Substances can have a number of heat (M-2).	7
	The heat is hot, while the temperature can be cold or hot (M-3)	5
	Cold object does not contain heat (M-4)	3
Heat transfer occurs due to temperature differences	The heat is hot, while the temperature can be cold or hot (M-3)	0
	There are two types of heat. Hot and cold heat (M-5)	9
	The heat is pulled by a cold object, so that heat and cold become neutral (M-6)	31
	Temperature can be transferred (M-7)	15
Heat moves from high-temperature objects to low-temperature objects	Cold object does not contain heat (M-4)	4
	The heat is pulled by a cold object, so that heat and cold become neutral (M-6)	18
	Temperature can be transferred (M-7)	40
The heat needed to raise the temperature is not only influenced by changes in temperature but also by the heat of the type and mass of the object	If the final temperature is higher, the more heat the object needs to increase its temperature (M-8)	11
	Heat is influenced by the volume of objects (M-9)	18
	Heat into objects of varying ease (M-10)	15
	Heat is only affected by the mass of the object (M-11)	7
	Different objects attract heat in different ways (M-12)	7
Heat is	Cold object does not	7

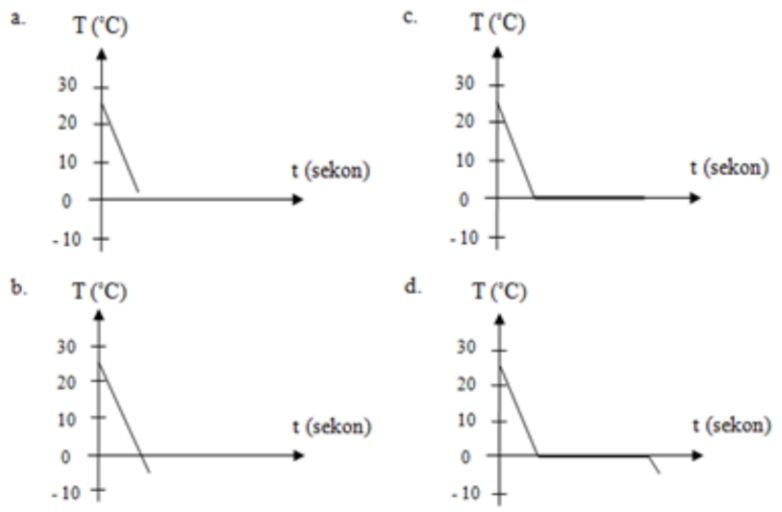
Scientific concept	Misconceptions that can be explored	Total
needed to convert the liquid into steam	contain heat (M-4)	
	The heat is pulled by a cold object, so that heat and cold become neutral (M-6)	34
	The air can cool things when the object is surrounded by air (M-13)	32
	Metals have the ability to attract, hold, strengthen or absorb heat and cold (M-14)	8
	Boiling point is the highest temperature that a substance can reach (M-15)	22
The temperature of the object does not change during changes in form	Boiling point is the highest temperature that a substance can reach (M-15)	21
	The temperature changes as long as the substance changes form (M-16)	29
	Water cannot be 0 ^{o} C (M-17)	5
	The ice temperature is always 0 ^{o} C or cannot be lower than 0 ^{o} C (M-18)	2

From Table 3, it can be seen that students demonstrated some of the same alternative conceptions about heat and temperature (Alfiani, 2015; Abbas, 2016; Celik, 2016; Fitzalen, et al. 2016; Fitriah, 2017; Silung et al., 2017; Sofianto et al., 2020). Students showed most common misconceptions is M-6, where as many as 83 students believe that heat is drawn by cold objects so that heat and cold become neutral. In fact, heat transfer occurs due to temperature differences. This misconception occur because of students' low understanding about heat. Students low understanding always been a major factor of misconception (Fitriah, 2017; Lestari & Linuwih, 2014).

In addition, students also believe that when temperature changes occur in objects that receive or release heat energy, this is caused by temperature transfer (M-7). Based on interview, students believe that the change in temperature caused by termperature transfer, not heat transfer. Fitriah (2017) who found the same problem also states that this misconception arise because of students' humanistic thinking. These misconceptions arise and developed by students based on observations of the phenomena they see everyday. There is a phenomenon of heat transfer, students can only see the visible temperature changes without understanding the concept microscopically. This is what causes students to assume that the one who moves is temperature instead of heat.

In addition, the misconceptions that are still quite experienced by students are M-13. Where as many as 32 students believe that air can cool objects around the object surrounded by air. Based on interview this misconception occur also due to students' observations in everyday life where hot objects left in the air can decrease in temperature. Even though this depends on the temperature difference between the observed system and the environment.

10. Air bersuhu 25°C didinginkan di dalam lemari pendingin hingga mencapai suhu -5°C. grafik yang benar dari pendinginan air tersebut adalah …



Alasannya …

a. suhu air turun hingga melewati titik beku dan suhunya mencapai -5°C.
b. suhu air turun hingga mendekati suhu 0°C, namun tidak bisa mencapai suhu 0°C karena air tidak dapat bersuhu 0°C.
c. suhu air turun hingga membeku pada suhu 0°C, selama membeku suhunya tidak berubah lagi. Setelah itu tidak akan terjadi penurunan suhu lagi karena suhu es akan selalu 0°C atau tidak bisa lebih rendah dari 0°C.
d. suhu air turun hingga membeku pada suhu 0°C, selama membeku suhunya tidak berubah lagi hingga semua air berubah wujud menjadi es kemudian suhu es akan turun hingga -5°C.

Seberapa yakin kamu dengan jawabanmu?

1	2	3	4	5	6

Figure 2. Question number 10.

There also 29 students who believe that temperature changes as long as the substance changes form (M-16). This result also found in Sofianto, et al., (2020), where students believe that when there is a change in temperature, there is a change of the form. In fact, when there is a change in temperature, it does not change the form. Alfiani (2015) states that this means students actually know that heat is needed in changing the form of objects but students do not know that during the process of it, heat does not cause changes in temperature. Based on interview, this misconception occur because students have difficulties in reading the graph in the question shown in Figure 2. As found in many studies (Albab, et al., 2020; Subali, et al., 2015; Sezen, et al., 2012), students ability in reading graph has strong correlation in their concept understanding. Therefore students who has low ability in reading graph are tend to have low conceptual understanding which can lead to misconception. To overcome students' misconception, the teacher's large role in learning is needed (Kambouri, 2015). The teacher should be able to choose the appropriate and enjoyable approach, model or method so that science learning becomes more meaningful. Additionally, before starting the learning process the teacher should pay attention to students' initial conceptions, especially in materials susceptible to misconceptions as to the

material temperature and heat. Based on studies by Sadler & Sonnet (2016) found that the teacher who know their students' most common misconception are more likely to increase their students' science knowledge. So that if students are identified as having misconceptions, the teacher must strive for learning that is not only focused on delivering material but also can help students improve their misconceptions.

CONCLUSION

Based on the results of the research and analysis of the data that has been conducted, it is known that there are still many students who do not understand the concept of temperature and heat so that it falls into the category of *lack of knowledges.* Besides that, even though they have studied the temperature and heat material in the 2nd semester of their 7th grade, students still experience 18 kinds of misconceptions.

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