Using Two-Tier Diagnostic Test to Identify Students' Misconceptions about Temperature

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Abstract. In this research, a 8-item two-tier diagnostic test was developed to identify students' understanding about the temperature concepts; which include understand the concept, lack of understand the concept, and misconceptions. The multiple-choice Temperature Concept Test (TCT) was administered to 88 participants (13 men, 75 women) as a two-tier test. The participants were selected using the convenience sampling method from the population of departemen of science education students in Gorontalo, Indonesia. The data were analyzed through quantitative and qualitative methods. The results of quantitative analysis shown that students percentage who have misconceptions were 53%, do not concept understand 31%, and concept understand 10%; and qualitative analysis, it was found that concept understand about temperature at least compared to those who have misconceptions and do not concept understand. Based on the research results, it can be concluded that the two-tier diagnostic test about the temperature that had been developed can be used to identify misconceptions, lack of understand the concept, and understand the concept. The physics education researchers can develop a two-tier diagnostic test into a multiple-tier diagnostic test on the temperature concepts or other physics concepts, then give it to students, teachers prospective or physics teachers to test the consistency level of previous research results.

Keywords: two-tier diagnostic test, misconceptions, physics education

1 Introduction

Physics concepts have a clear meaning according to the agreement of physicists, while students have initial concepts of physics. Students' initial concepts are the most important aspect for students to actively involved in the learning process [1, 2]. Students' initial concepts constructed in their cognitive structure through teaching and learning process in formal school or informally through their everyday experiences. Because the students constructed their own knowledge, then the students' initial concept that conflicts with concept of teachers or physicists are labeled: misconceptions, naïve conceptions, children's science, alternative conceptions, or conceptual frameworks [3–13]. Misconceptions are students' ideas that different from definitions accepted by experts [14–16]; sourced from students' experiences, textbooks, language used, and teachers

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[17]; and often creates misinterpretation and misconstruction [1]. Students' misconceptions are difficult to convert into correct concepts according to the experts [18–23].

Misconceptions occur in all physics concepts [24], including Temperature and Termometer concepts. Students' misconceptions must be overcome, avoided or eliminated so that students achieve physics experts understanding [1][18–22] [25] because students' misconceptions are developed, strongly embedded, and stable in their cognitive structures [25–28]. Misconceptions hinder acquisition of valid concepts about a natural phenomenon hinder effective learning [29], and resistant to change. Therefore; identifying, recognizing, diagnosing, checking and rectifying the students' misconceptions as early as possible is very important.

Many Indonesian and foreign researchers in area of physics education conducted research about students' misconceptions [1][19][22, 23][27][30–35], especially using diagnostic test instruments to identify and uncover students' misconceptions [14][36–42]. According to Kirbulut and Geban (2014) that diagnostic tests are a novel and they provide us to distinguish misconceptions from lack of knowledge via an extra tier that require students to state whether or not they are sure about their answers. Another definition that diagnostic tests are assessment tools which are concerned with the persistent or recurring learning difficulties that are left unresolved and are the causes of learning difficulties [38]. Several researchers [1][38][42, 43] said that using diagnostic tests, the teacher can be identify the students' initial concepts who experience misconceptions, lack of knowledge, and concept understand, and the teacher can also develop and utilize alternative learning methods to overcome learning difficulties and student misconceptions.

In recent years, several diagnostic test instruments can be used to identify and uncover students' misconceptions, one of which is the multi-tier test. Multiple-tier test is a diagnostic test instruments consisting of two-tier test, three-tier test, and four-tier test [1]. The two-tier tests were exlanated as diagnostic instruments with first tier involves a multiple-choice question about the concept, and the second tier involves a multiple-choice question about the reasons for the answer to the first tier question [38][44–46]. According to [47] that the two-tier diagnostic instruments are relatively convenient for students to respond to and more practical and valuable for teachers to use in terms of reducing guesswork, allowing for large-scale administration and easy scoring, and offering insights into students' reasoning.

Based on these reasons, this research aimed to identify misconceptions, lack of understand the concepts, and understand concepts at departement of science education students on the topic of temperature and thermometer through two-tier multiple choice test instrument. Another reason is that university students have constructed their own knowledge about temperature and thermometers since they were in secondary school and high school so that their initial concepts still have the opportunity to experience misconceptions, lack of understand the concepts, or understand the concepts according to the concepts accepted by physicists.

2 Method

In this research, constructing a two-tier diagnostic test on temperature topic used development model "Define, Design, Develop and Implementation" [48]. The define stage was identify concepts on temperature and thermometer based on literature review. The design stage, designed product initial prototype about a two-tier diagnostic test consisting ordinary multiple choice test questions (Tier-I) and confidence of level (Tier-II). The develop stage, developed the ordinary multiple choice test (Tier-I) on the topic of temperature and thermometers and confidence of level (Tier-II) into a two-tier diagnostic test, conductet the content validaty index (CVI) test and reliability test use Kuder-Richardson formula 20 (KR-20), then administered to 88 students of the Science Education Departemen in Gorontalo at the implementation stage. The quantitative data obtained from test results were presented in percentage form, while qualitative data was presented as significant data. Furthermore, the categorizing of students' conceptions used the combination about of the answers accurate of ordinary multiple choice test and confidence of level in answers provided [49, 50] with the assessing rubric at the categories, namely misconceptions (MC), understand the concept (UC), lack of understand the concept (LUC).

3 Result and Discussion

The two-tier diagnostic test was developed to indentify students' conceptions on temperature concepts, including thermometer. The research used development model "Define, Design, Develop and Implementation. The explanation of each stage is as follows.

Define

Temperature is microscopic and invisible concept, but its effects can be felt. Based on the literature review, the identify results of concepts on the topic of temperature and thermometers at the define stage, include four concepts, namely temperature, temperature unit, temperature of zero kelvin, and comparasion of thermometer scales.

Design

Based on the identify results of concept at the define stage, a design eight two-tier diagnostic test items was produced on the topic of temperature and thermometers at the design stage. An example of the design results of a two-tier diagnostic test is presented in table 1.

(Adapted:[51])

Develop

The design about two-tier diagnostic test consists of the ordinary multiple choice test pada tier-I and tier-II containing a confidence of level in providing answers in tier-I. An example of test item on temperature concept in form a two-level diagnostic test is presented in table 2.

Table 1. Design a two-tier diagnostic test

Concept Question:
Ordinary multiple choice answers (Tier-I)
A. Option for the first answer choice
B. Option for the second answer choice
C. Option for the third answer choice
D. Option for the fourth answer choice
E. Option for the Fifth answer choice
Confidence of Level Question (Tier-II):
A. Alternative choice if "Yes, I am sure" of the answer chosen
B. Alternative choice if "No, I am not sure " of the answer chose

Table 2. An examples a two-tier diagnostic test on the temperature concept

1.1 What best describes about the definition of temperature ?
A. The measure of the amount of heat in an object
B. The measure of particles in an object
C. The measure of light emission from an object
D. The measure of interaction of particles in an object
E. The measure of particles distance in an object
1.2. Are you sure about your answers at 1.1.
A. Yes, I am sure.
B. No, I am not sure.

Furthermore, a two-tier diagnostic test that has been developed (3 items on the concept of temperature, 3 items on the cenocept of zero kelvin temperature, and 2 items on the equality of the indication scale between two thermometers) is tested for the level of validity and reliability. The validity and reliability of the two-tier diagnostic test were analyzed to ensure that the instruments are valid and reliable criteria. The Content Validity Index (CVI) has traditionally been use to estimate representativeness, comprehension, ambiguity, and clarity [52–54] For each item, the CVI is calculated by dividing the number of validators who gave a rating of 3 or 4 on the corresponding Likert scale by the total number of validators [55]. As a general criteria, the CVI value is said to be valid if it is equal or greater then 0.70 [54]. The CVI assessing results for a two-tier diagnostic test are presented in Table 3.

The data presented in Table 3 shown that to eight test items that have been developed can be declared valid (CVI ¿ 0,70). The CVI value is highest at the items 1, 3, 4, 6, and 7. Thus, all items of the two-tier diagostic test that have been developed can be used to estimate of aspects representativeness, comprehension, ambiguity, and clarity [52] [54].

Implemantation

In the implementation stage, the two-tier diagnostic test that has been developed was tested to 88 science education departement students in the academic year 2023/2024. Before the data analysis, reliability tests were conducted. Reliability is related to the extent to which a measuring instrument or test can provide stable and consistent results [56]. Reliability is also related to a test is can be said to be reliable if measurements

Table 3. The validity result used the Content Validity Index (CVI).

Item	Validator					CVI	Criteria
	1	2	3	4	5		
1	1	1	1	1	1	1,00	Valid
2	1	1	1	1	0	0,80	Valid
3	1	1	1	1	1	1,00	Valid
4	1	1	1	1	1	1,00	Valid
5	1	1	1	1	0	0,80	Valid
6	1	0	1	1	1	1,00	Valid
7	1	1	1	1	1	1,00	Valid
8	1	1	0	1	1	0,80	Valid

carried out repeatedly under constant conditions will give the same results [57]. Hinton was suggested calculated values for the reliability coeffigient, namely 0.70 to 0,90 is called high reliability [58]. The calculation of the reliabilty coefficient with KR-20 was obtained to be greater than 0,70 or high reliability [58].

Table 4. The assessing rubric of a two-tier diagnostic test

No.	Categories	Combination of answers	
		Ordinary multiple choice test opstions (Tier-I)	Confidence of levels options (Tier-II)
1	Misconceptions (MC)	Incorrect	Yes, I am sure
2	Understand the concept (UC)	Incorrect	Yes, I am sure
3	Lack of understand the concept (LUC)	Incorrect	No, I am not sure
		Correct	No, I am not sure

(Adapted: [48][59]).

The assessing rubric at the categories of misconceptions (MC), understand the concept (UC), and lack of understand the concept (LUC) based on a two-level diagnostic test on the topic of temperature and thermometers was presented in the table 4.

The next, about students' profile of the science education departemen who have misconceptions, understand the concept, lack of understand the concept as presented in table 5.

The data in table 5 shown that science education departement students' conceptual understanding were very concerned. It is said this because the percentage of students who have misconceptions are much greater than the students who have scientific knowledge (understand the concepts) about temperature and thermometers, namely 53% compared to 10%. Likewise, the students who have a lack of understand the concept are 37%.

The data about students' misconceptions and lack of knowledge is the focus of attention in learning about temperature and thermometers. According to [[51] that findings and modifications of misconceptions in physics education into scientific concepts has been conferred [33]. Besides, table 5 also shown that the number of science education department students who experience misconceptions about each concept label about temperature and thermometers is quite large, even though they have been learn-

Table 5. Students' profile of misconceptions, understand the concept, and lack of understand the concept on the temperature

Number of concept	MC (%)	UC (%)	LUC (%)
1	66	16	18
2	60	11	29
3	53	14	33
4	68	11	21
5	57	12	31
6	64	9	27
7	30	5	65
8	26	5	69
Average	53	10	37

ing about temperature and thermometers at the elementary schools, secondary school and high school levels or equivalent. This incident can not be sparated from the learning process in the classroom where the teacher is unable to embedded the scientific concepts in students' cognitive structures.

The learning observations results show that learning using the lecture method, conventional models or traditional approaches does not matching to the temperature characteristics that invisible and requires visualization media that can model the movement of particles when temperature changes occur in objects [51].

4 Conclusion

In this research, the design of a two-tier diagnostic test on the topic of temperature and thermometer has been successfully developed. The development or construction results of a two-tier diagnostic test has been shown effectively to identify the students who have scientific concepts (10%), lack oft understand concepts (37%), and who experience misconceptions (53%). From this research, the lecturers or teachers need to use visualization media, for example using Physics Education Technology (PhET) simulations in the learning process as an effort to minimize the occurrence of misconceptions. The researchers (lecturers or teachers) can be develop a two-tier diagnostic test into a four-tier diagnostic test, and compare the results, which one is more effective in reducing the occurrence of misconceptions.

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