Identification student’s misconception of heat and temperature using three-tier diagnostic test

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Abstract. The objective of this research is to develop a Three-Tier Diagnostic Test (TTDT) to identify the student's misconception of heat and temperature. Stages of development include: analysis, planning, design, development, evaluation and revise. The results of this study show that (1) the quality of the three-tier type diagnostic test instrument developed has been expressed well with the following details: (a) Internal validity of 88.19% belonging to the valid category. (b) External validity of empirical construct validity test using Pearson Product Moment obtained 0.43 is classified and result of empirical construct validity test obtained false positives 6.1% and false negatives 5.9% then the instrument was valid. (c) Test reliability by using Cronbach’s Alpha of 0.98 which means acceptable. (d) The 80% difficulty level test is quite difficult. (2) Student misconceptions on the temperature of heat and displacement materials based on the II test the highest (84%), the lowest (21%), and the non-misconceptions (7%). (3) The highest cause of misconception among students is associative thinking (22%) and the lowest is caused by incomplete or incomplete reasoning (11%). Three-Tier Diagnostic Test (TTDT) could identify the student's misconception of heat and temperature.

1. Introduction

Learning is a teacher's effort to help students do learning activities to gain knowledge [1-8]. Physical learning is the acquisition of knowledge developed by students in accordance with the cognitive preparedness of each [9-14]. However, the reality found many students studying physics is not interested and has no understanding after learning physics [15-22]. The results of previous research literature studies have found that there are still many students who experience misconceptions [19-26]. Misconception is a conception that is inconsistent with the conception advanced by the experts, so that students have difficulty learning physics. Misconception is a problem that needs to be reduced because if misconception is left it will be a barrier to students in learning the next material. Misconceptions occur not only among students, but occur throughout education, including students and teachers. Misconceptions are difficult to change in the self because each student builds his knowledge with the experience they have.

Misconceptions in physics include: (1) Preconception occurs when students have not followed formal learning, the students have already had an initial concept based on their experience and the phenomenon of everyday life. (2) Associative thinking has occurred when misinterpreting the terms scientific concepts or the relationship between concepts and other concepts. (3) Humanistic thinking, students think that the nature of the object or the behavior of analogous things such as human nature. (4)
Incomplete reasoning is caused by incomplete information so that the students draw wrong conclusions other than it happens because of wrong logic in taking conclusions or in generalizing. (5) Wrong intuition, usually derived from continuous observation, resulting in a spontaneous feeling when faced with the problem. (6) The stage of cognitive development of students has influenced misconception because students have not been able to abstract a problem to be solved. (7) Ability of students, students who are less talented physics or less able to study physics so that difficulty in capturing the correct concept in the learning process. (8) Student interest in the form of low talent or level of intelligence that exist in students as a basis for understanding a scientific concept [19-26]. Specifically more misconceptions have been found in heat and temperature materials [23-26] including (1) misconceptions of heat and temperature topics of respondents difficult to identify temperature and heat differences. (2) misconceptions for heat and temperature material at undergraduate level is 5% sub temperature chapter and 48% sub heat at master student 4% sub chapter temperature and 49% sub heat and for doctoral program 7% sub chapter temperature and 40% sub chapter heat. (3) Supported by the results of preliminary tests on January 22, 2016 from 36 Unesa students class of 2014 it was found that 59% misconceptions at subheading temperature, 40% in the heat subspace as change of form, 58% on heat and temperature change and 50% on sub-chapter of heat transfer by assuming better student ability than students. From the results of these studies stated that the material temperature, heat and heat transfer of almost all students have an understanding of the concept itself and many still experience misconception.

The results are reinforced by the results of preliminary study at State Senior High School of 1 Sooko Mojokerto. (1) The results of interviews in March 2016 with one of the physics teacher at State Senior High School of 1 Sooko Mojokerto, the results of daily physics test that reached 75% PG and the value of national examination subjects physics in 2015 at State Senior High School of 1 Sooko Mojokerto averages 78.78 highest to three after Indonesian and English. (2) The average student in State Senior High School of 1 Sooko Mojokerto has achieved the learning objectives made by the teacher but, in order to achieve the basic competency the students are still experiencing learning difficulties. (3) Daily repeats given mostly only in the realm of application (C3) that is applied. (4) There is no comprehension of the concept of students as a whole. (5) The teacher has not maximally detected the location of student learning difficulties. Based on these facts there is a problem that must be solved that is necessary early detection to detect misconceptions of high school students and as a basic idea to develop learning that can reduce misconceptions of high school students.

Diagnostic tests are tests used to identify student weaknesses so that proper handling is possible [27-31]. Benefits diagnostic test can be used by teachers to know the level of mastery of student concepts, lack of knowledge, misconception, and difficulties learning [27-31]. Diagnostic tests such as multiple choice and two-tier tests are less efficient to identify misconceptions widely, test results are not sufficient enough to describe misconceptions of lack of knowledge. The alternative is a three-tier test to diagnose student misconceptions on physical materials. The three-tier type diagnostic test is an activity of constructing multiple-choice tests [32-39]. At the first level includes a regular multiple choice test, at the second level covers the reason of the selected answer from the first level and at the third level is the confidence level of the selected answer. Students answer on each item considering the truth. For example, students answer wrongly on the first and second level and have high confidence at the third level then the student misconception. The three-tier test on physics material is very accurate for measuring student misconceptions from lack of conceptual understanding, misconceptions to not understanding the concept [40-41]. Based on literature study and preliminary study there is a problem that must be solved that is need to detect and diagnose misconception of high school students in physics material using Three-tier test. The results of this study will be used as a basic idea and empirical evidence to develop learning that can reduce misconceptions of high school students on the material physics. The research problem in this study as follows:

a. How are the qualities of Three-Tier Diagnostic Test (TTDT) developed?
b. What is the profile of student misconception on the temperature, heat, and displacement material through a Three-Tier Diagnostic Test (TTDT)?
c. What is the result of identifying the causes of student misconceptions on the temperature, heat, and displacement materials through a Three-Tier Diagnostic Test (TTDT)?

2. Methodology of Research

2.1. Sample
This research was conducted at State Senior High School of 1 Sooko Mojokerto with research subjects of three classes of X MIA, ie X MIA 1, X MIA 2, and X MIA 3. The research was conducted in State Senior High School of 1 Sooko Mojokerto in the even semester of academic year 2015-2016. Initial trials were conducted in January 2016, I Trial and II trial in April 2016 in 30 students.

2.2. Procedure
This type of research is a developmental study with the development method proposed by [2]. In this study developed a Three-Tier Test Diagnostic Test (TTDT) instrument on the temperature, heat, and displacement materials. Design instruction [2] there are five stages: analysis, planning, design, development, evaluation and revision are described as follows.

1. The analysis stage includes: (a) Analysis of problems based on literature; (b) Analysis of the temperature, heat, and displacement material; (c) Identify the student's initial concept.

2. The planning stage includes: (a) Place of study; (b) Choosing the form of questions; (c) Selects diagnostic test instruments related to the temperature, heat and displacement materials.

3. Design stage, Preparation of three-tier type diagnostic tests as follows: (a) Prepare the diagnostic test gratings; (b) Prepare a diagnostic test; (c) Preliminary trials to determine the choice of answers to the causes of misconceptions on the second level with first-degree answer options for divers; (d) Evaluate the preliminary test results and revise the diagnostic test instrument.

4. The development stage includes: (a) Developing a three-tier diagnostic test on the basis of closed answers; (b) The preparation of a three-tier diagnostic test begins with the preparation of reasons at the second level. Preparation of second-level reasons based on preliminary trial results to categorize the causes of misconceptions so that a closed three-tier diagnostic test is obtained. Selection of three-tier diagnostic test is closed to make it easier to analyse the causes of student misconceptions; (c) Design validation, design validation is used to generate quality questions, at this stage validated content, language, and conformity with basic competence by the experts ie two physics lecturers then revise the diagnostic test instruments based on the input of the validator and the developed instrument is declared valid; (d) Test I, Test I conducted on students of State Senior High School of 1 Sooko Mojokerto as many as 50 students, to determine the validity, reliability, level of difficulty, and different instruments that have been made of 20 items; (d) Problem quality analysis, this quality analysis is used to determine the validity, reliability, differentiation, and degree of instrument difficulty as well as determine the number of good quality questions used to identify student misconceptions. Selected 19 questions from 20 questions that meet the quality of the good question; (e) II Trial, II Trial to students of State Senior High School of 1 Sooko Mojokerto X class MIA 3 as many as 30 students.

5. Analysis phase includes: (a) Conducting data analysis from result of II trial to identify student misconception and its misconceptions cause 30 students of class X MIA 3; (b) Make a report of research results.

2.3. Instrument
The TTDT is a 19-item consisting of three tier items for assessing students’ understanding of state of mater concepts. The first tier consists of ordinary multiple choice questions with five choices. The second tier includes one correct reason and 4 alternative reasons. The alternative reasons are the misconceptions identified from open-ended questions and then make cause of misconceptions as humanistic thinking, associative thinking, preconception, intuition, and partial reasoning. The third tier requires students to state how confident they are about their answers for the first two tiers. The TTDT
examines the conceptual area of temperature and thermal equilibrium (5 items), concept heat 8 item (thermal capacity, changed phase functions, thermal changed of heat) and heat flow (6 item). For known about student’s conceptions, table 1 is combining of result three-tier diagnostic test.

| Type diagnostic | Three-tier | Combine of result | Category        | Code |
|-----------------|------------|-------------------|-----------------|------|
|                 | T + T + Agree | Sound understanding | SU              |
|                 | T + F + Disagree | Partial understanding | PU              |
|                 | F + F + Disagree | Lack knowledge | LK               |
|                 | F + T + Disagree | Riddle | R                |
|                 | T + F + Disagree |               |                  |
|                 | F + F + Agree | Misconception | M                |
|                 | F + T + Agree |               |                  |
|                 | F + F + Agree |               |                  |

2.4. Data Analysis

2.4.1. Analysis of Three-Tier Test Diagnostic Test (TTDT) quality. The instrument to be used should be a good instrument of quality by calculating the validity, reliability, difficult level, and different power [42-43].

2.4.2. Analysis of misconceptions by percentage. Categorize the results of all students' answers by using equation (1). This percentage result illustrates the conception of students from concepts, lack of conceptualism, not understanding concepts, misconception, and guessing, then every misconception is analysed.

\[
P_{kj} = \frac{n_i}{N_s} \times 100\%
\]

Explanations:
PKJ = result percentage
ni = quantity students conceptions (SU, PU, LK, R, M)
Ns = all of sample

2.4.3. Analysis of the causes of misconceptions. The result of the calculation of the students entering the misconception group is why it is grouped based on the causes of misconception which includes preconception, associative thinking, humanistic thinking, incomplete (wrong) reason, and false intuition; these results are then analysed and can be calculated by equation (2).

\[
P_{PM} = \frac{n_i}{N_m} \times 100\%
\]

Explanations:
PPM = percentage cause of misconceptions
ni = quantity cause of misconceptions either one
Nm = all off students misconception.

3. Result of Research

3.1 The quality of Three-Tier Test Diagnostic Test (TTDT)
Instrument has been developed

3.1.1 Internal validity of Three-Tier Test Diagnostic Test (TTDT) Internal validity validated by two expert lecturers of 88.19% belong to valid category. After doing the assessment of internal validity then
conducted experiment I with a sample of 50 students of State Senior High School of 1 Sooko Mojokerto to know the external validity of the instruments that have been developed.

3.1.2 External validity of Three-Tier Test Diagnostic Test (TTDT). External validity of empirical validity test constructs using Pearson Product Moment obtained = 0.43 are classified and empirical construct validity test results obtained false positives 6.1% and false negatives 5.9% then the instrument is said to be valid.

3.1.3 Reliability of Three-Tier Test Diagnostic Test (TTDT). Test reliability of three-tier diagnostic test by using Alpha Cronbach’s of 0.98 which means it can be accepted.

3.1.4 Difficult Level of Three-Tier Test Diagnostic Test (TTDT). The 80% difficulty level test is 20% moderate and 80% categorized as difficult.

3.1.5 Different power of Three-Tier Test Diagnostic Test (TTDT). The diagnostic test instrument developed 45% in sufficient category and 55% in the bad category, so 55% of the developed instruments cannot distinguish clever and clever students, but they can still be used to diagnose student misconception profiles. Recapitulation of result of instrument quality test based on validity, level of problem difficulty, different power with reliability 0.98.

3.1.6. Student misconceptions profiles on temperature, heat, and displacement materials through a three-tier diagnostic test

The II trial results of the Three-Tier Test Diagnostic Test (TTDT) type of temperature, heat and displacement were given to the students of grade X MIA 3 State Senior High School of 1 Sooko Mojokerto who had obtained the temperature, heat, and displacement materials. Three-Tier Test Diagnostic Test (TTDT) consists of 19 questions that have met the quality of the instrument a good question. The problem consists of three multiple-choice levels. The first level is the answer to the question that has five answers for the cognitive domain of C4 (analyse) and C5 (evaluate) whereas for C6 has six answers and the sixth answer is an empty answer option because, C6 (create) is the cognitive domain of students' freedom to be creative. The second level is the choice of reason consisting of 5 reasons for the deception (indicating the cause of misconception), one true reason and the choice of the last reason is an empty excuse. This empty excuse is used for students who disagree with the choice of reasons already provided, so that students express in their own language. The third level is a belief of both levels that have been answered. Misconceptions of the students of grade X MIA 3 State Senior High School of 1 Sooko Mojokerto have temperature material of heat and displacement based on the highest test of 84%, 21% low and non-misconception 7%.

![Graph students’ conception in sub the subject.](image)
Based on Figure 1 it is seen that students as a whole have misconceptions on the temperature, heat and displacement materials. Students experiencing the highest misconception on the material sub-heat can change the temperature of objects, heat capacity, and heat type of 60% and 18.25% of students understand the concept. 80% of students consider the heat capacity to be proportional to temperature change and cannot distinguish between the concept of heat transfer (conduction) and the parallel event i.e. heat can change the temperature of the object and the heat is used to change its shape. In sub heat material can change the form of objects 58% of students experiencing misconception and 16.6% of students understand the concept. In this sub-material 77% of students assume that water whose particles bond more closely than gas has higher energy and considers that adding heat to an object always leads to an increase in the temperature of the object. In the matter of heat transfer 51.5% of students who experienced misconception, while students who understand 24.3%. 67% of students experiencing misconceptions do not even understand the concept of material conductivity. In the sub temperature and thermal equilibrium matter the percentage of students who understood the highest concepts than the other sub-material is 26% and the student percentage of students with the lowest misconception than the other sub material is 47.5%. In this sub-material 60% of students assume that the plastic container is temperature higher than the liquid in the container and the student has not understood the concept of thermal equilibrium.

3.1.7. Result of identification of the cause of student misconception on temperature, heat, and displacement material through three-tier diagnostic test

The causes of misconceptions that come from students can only be analyzed in five categories of eight categories namely preconceptions (P), wrong intuition (I), wrong reasoning (R), humanistic thinking (PH), and associative thinking (PA). For the other three categories of cognitive developmental stages, students' abilities and student learning interests cannot be detected using these developed instruments. The student's cognitive development has been mapped out by Piaget by age so that it can be assumed that the cognitive development of the class X students is the same. Figure 2 shows that the highest cause of misconception in the high misconception category is associative thinking so that it can be said that the students in the high category experience misconception after obtaining the temperature, heat and displacement material and this student wrongly concepts one concept with the other. The highest cause of student misconception in the medium misconception category is faulty intuition so students spontaneously answer the phenomenon in the question. In the low misconception category the highest misconception is preconception, so before getting formal material in school students have gotten the wrong concept from their experience. The cause of student misconception on the temperature sub-matter and the highest thermal equilibrium is faulty intuition, students respond spontaneously about the given phenomenon.

![Figure 2. Percentages cause of students misconception.](image-url)
In sub heat matter can change the form of objects that cause the highest misconception is associative thinking. It can be said students learn on this sub-material mix with other concepts. The causes of misconceptions experienced by students in the material sub-heating and temperature changes of objects, heating capacity, and the highest body heat are due to a preconception which means students have learned before attending formal schooling based on their experience. The cause of the misconception on the highest substantial heat transfer material experienced by students is the faulty intuition that students spontaneously respond to the phenomenon in question.

4. Discussions
The quality of the Three-Tier Test Diagnostic Test (TTDT) instrument that has been developed is stated well with the following details: (a) internal validity validated by two expert lecturers of 88.19% belong to valid category. (b) External validity of empirical construct validity test using Pearson product moment obtained = 0.43 is classified and result of empirical construct validity test obtained false positives 6.1% and false negatives 5.9% then the instrument is said valid. (c) Test reliability by using Alpha Cronbach’s of 0.98 which means acceptable. (d) The 80% difficulty level test is classified and the 55% different test is classified as bad, although the differentiation and degree of difficulty is difficult and difficult to use because the diagnostic test function is to know students' learning difficulties not to distinguish interpersonal skills [31]. The results of this study received empirical support from previous studies that a qualified three-tier diagnoses test can be used to diagnose student misconceptions [27-31]. Diagnostic tests can be used to identify students' weaknesses so that appropriate handling can be done [27-31]. The three-tier diagnoses test in physics material is very accurate for measuring student misconceptions from lack of conceptual understanding, misconceptions to not understanding the concept [40-41].

Based on Figure 1, the trial results of the Three-Tier Test Diagnostic Test (TTDT) type of temperature, heat and displacement are given to students of class X MIA 3 State Senior High School of 1 Sooko Mojokerto who have obtained the material temperature, heat, and displacement. Three-Tier Test Diagnostic Test (TTDT) consists of 19 questions that have met the quality of the instrument a good question. The problem consists of three multiple-choice levels. The misconceptions that occur in the sub-material temperature and thermal equilibrium as much as 47% of the 30 students, namely on the concept: (a) Temperature, According to the students’ temperature is not the result of thermal equilibrium between the system and the environment. (b) Thermal equilibrium The factor of occurrence of thermal equilibrium according to the student is influenced by: (1) the thickness of the object, the thinner the faster the thermal equilibrium; (2) The surface area the larger the surface area the faster the thermal equilibrium; (3) The material of the object, as well as the thermal equilibrium, never occurs on two objects having different materials although they are contacted in the same room. 58% of the 30 students of misconception on the sub-matter of heat can alter the existence of objects, that is, in concept (a) when the change in the form of ice becomes water, the water is never at 0 ° C and the ice never keeps the heat. (b) When the change in the form of water becomes a gas, the vapour mass is lighter than the water mass. (c) The heat used to change the form is affected by the heat, mass and surface area and shape of the object.

Misconceptions on sub heat material can change the temperature of the object at most 60% of the 30 students that is on the concept: (a) The heat capacity of the students considers the heat capacity is proportional to the temperature change of the object, so the greater the heat capacity the faster the object undergoes temperature changes. (b) The heat used for temperature change is affected by the surface area and is considered a conduction process (c) Lack of skill to relate magnitudes in thermodynamics i.e. type heat and latent heat in graphical form. In the sub-matter of heat transfer from 30 students experiencing misconceptions of 50% i.e. on the concept. (a) Conduction, understanding students about the concept of conduction is a cold flow event and conduction is proportional to the capacity of heat and latent heat. (b) Emissivity, Students understand the concept of emissivity is the ability to absorb it only for grey matter (real body). (c) Reflectivity, Reflexivity is the ability to radiate heat for a body of grey
Figure 2 shows that the causes of misconceptions derived from students can only be analyzed in five categories from eight categories namely preconceptions (P), wrong intuition (I), wrong reasoning (R), humanistic thought (PH), and associative thinking (PA). The analysis causes of student misconceptions. Based on the results of misconception analysis and the causes of the students of class X MIA 3 State Senior High School of 1 Sooko Mojokerto can be mapped according to sub-material to be as follows. The cause of student misconception on the temperature sub-matter and the highest thermal equilibrium is faulty intuition, students respond spontaneously about the given phenomenon. Suppose the students spontaneously that the temperature of the plastic bottle is higher than the canned drink even though both are placed in the same place. In sub heat material can change the form of objects that cause the highest misconception is associative thinking that is equal to 24%. It can be said that students learn on this sub-material mix with other concepts. As well as on the phenomenon of comparing the energy that gives the worst impact of burns between water and water vapor. Students associate with the concept of heat capacity, the students believe that the steam heat capacity of water is higher than that of water so that it has greater energy and gives more burns. The concept of heat capacity is already great but it becomes a misconception because in that case the impact of burns is the bonding of the free gas particles making it easier to penetrate the skin.

The causes of misconceptions experienced by students in the material sub-heating and temperature changes of objects, heating capacity, and highest body heat are due to preconceptions which mean students have learned before attending formal schooling. One of them is the students have learned based on his experience one of them is the observation about the ice for melting faster than the ice chunk, so more quickly lower the temperature. The cause of the misconception on the ultimate heating material substance that students experience is false intuition. One example is the students think that the conduction process that flows is cold instead of heat. Based on the above exposures the highest cause of misconception on the temperature sub is the faulty intuition of 15%, in the heat sub material is a preconception of 23% and in the sub-matter of heat transfer is an incorrect intuition of 18%. The results of this study are well supported by previous research that there are still many misconceptions in the matter of heat and temperature [23-26]. The above description shows that the Three-Tier Test Diagnostic Test (TTDT) developed in this study has been shown to detect and diagnose the causes of student misconceptions on heat and temperature materials.

5. Conclusion
The results of this study show that (1) The quality of the three-tier type diagnostic test instrument developed has been expressed well with the following details: (a) Internal validity validated by two expert lecturers of 88.19% belonging to the valid category. (b) External validity of empirical construct validity test using Pearson Product Moment obtained 0.43 is classified and result of empirical construct validity test obtained false positives 6.1% and false negatives 5.9% then the instrument was valid. (c) Test reliability by using Cronbach’s Alpha of 0.98 which means acceptable. (d) The 80% difficulty level test is quite difficult. (2) Student misconceptions on the temperature of heat and displacement materials based on the II test the highest (84%), the lowest (21%), and the non-misconceptions (7%). (3) The highest cause of misconception among students is associative thinking (22%) and the lowest is caused by incomplete or incomplete reasoning (11%). Three-Tier Diagnostic Test (TTDT) could identify the student's misconception of heat and temperature. Implications and further research include: (1) the need for physics learning that develops conceptually before solving the physics and theoretical problems in order to reduce misconceptions. (2) Research findings can be used as a reference for teachers using a three-tier test to detect misconceptions. (3) For further research it is necessary to observe the learning process in the classroom in order to explain the cause of the complete misconception.
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