Effect of problem type toward students’ conceptual understanding level on heat and temperature

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Abstract. The aim of this research is to analyze the level of students' understanding of heat and temperature concept and effect of problem type toward students’ conceptual understanding of heat and temperature. This research is descriptive research with the subjects of the research are 96 students from high, medium, and low categorized school in Surakarta. Data of level of students’ conceptual understanding is from students’ test result using essay instrument (arranged by researcher and arranged by the teacher) and interview. Before being tested in the samples, essay instrument is validated by the experts. Based on the result and the data analysis, students’ conceptual understanding level of 10th grade students on heat and temperature is as follows: (1) Most students have conceptual understanding level at Partial Understanding with a Specific Misconception (PUSM) with percentage 28.85%; (2) Most students are able to solve mathematic problem from teacher, but don’t understand the underlying concept.

1. Introduction

The aims of physics learning process at school are to develop students' thinking skill, to provide knowledge, understanding and to develop science and technology [1]. One of an important subject in the curriculum is physics, because of its contribution to the development of science and technology in society [2]. The right Physics learning process should develop conceptual change. Both changes in the form of expanding the concept, as well as change the wrong concept to be true, so that it can apply the concept to solving the problem [3]. Therefore, conceptual understanding is the most definitive thing towards the achievement of Physics learning goals.

The concept in physics learning become an important key to understanding and applying physics in daily life. The concept allows us to understand new experiences by connecting with what we already know. Scientific concepts are media that help to understand its application in everyday life. Scientific concepts are expressed on many levels, from very extensive labels to biology, physics, earth, etc., where the concept is presented in schools and generalized in standard reports or curricula [4].

The physics learning process guides students to be able in finding concept with its way. Therefore, teachers must be able to explore and to develop students’ concept. Students should get many opportunities to use their logical reasoning skill, training, formulating a concept and participating in solving complex problems that need their hard effort. Then, students are encouraged to be able in creating accurate conclusion [5].

A good understanding of the physics concept leads students to be able to construct new concepts in other ways in different representations. A good understanding of concepts can make students be skillful in such as remembering, explaining, finding facts, mentioning examples, generalizing,
applying, analogizing, and expressing new concepts in other ways [6]. These skills are necessary to physics learning in schools.

Conceptual understanding in physics teaching learning process has been the concern of many researchers. Other studies have revealed a conceptual understanding of physics on various topics [7, 8, 9, 10, 11]. Conceptual understanding makes students can transform knowledge become multiple representations and apply in daily life. Conceptual understanding of various physics concepts that have been obtained at schools can use as adequate basis for the advancement and development of science and technology in society [12].

Profile of students’ conceptual understanding level known with appropriate problem type. Based on an interview with physics teachers, most of the teachers focused on mathematics problem than a conceptual problem. Science teachers more value on mathematic learning (algorithms learning) than conceptual understanding giving students who studied in science have the impression that science is “math in disguise” [13]. Students’ failure to mixed science and math leads students to transform science problem solving to mathematics problem solving [14]. So, to know conceptual understanding in science need appropriate problem type that not confused with mathematics understanding or algorithms understanding.

Heat and temperature are one of physics materials that have the low conceptual understanding. Many students still difficulty in understanding heat concept and thermodynamic [15, 16, 17, 18]. The most difficult concepts are differentiating between heat and temperature [16, 19]. Therefore, it needs analysis on students’ conceptual understanding level on that material so that teachers can recognize how far students’ conceptual understanding and teachers can carry out the appropriate step. By knowing the students’ conceptual understanding level, teachers can determine the appropriate learning model so that learning indicators can be achieved [11].

Based on the theoretical above, the researcher has conducted studies to investigate the students' conceptual understanding level on 10th-grade students in Surakarta on heat and temperature and effect of problem type arranged by the teacher. An analysis of the level of students' conceptual understanding uses essay test as an assessment instrument.

2. Experimental Method
This research is a descriptive research aimed to describe the level profile of students' conceptual understanding. Subjects of the research are 10th-grade students in the academic year of 2016/2017. It consists of 96 students from one class in every school (high, medium, and low categorized school) in Surakarta. The category of the school is based on the four latest score of a national exam. Data of level of students’ conceptual understanding is from students’ test result using essay instrument (arranged by researcher and arranged by the teacher). The data will be used to analyze the students’ conceptual understanding level to get students' profile that shows the level of conceptual understanding for each student and to know the effect of problem type toward students’ conceptual understanding. Data is also collected through interview. The interview is used to confirm and to explore students’ conceptual understanding.

3. Result and Discussion
The instrument used to analyze the level of students' conceptual understanding is essay questions that consist of 10 numbers. The aim of free essay test is to avoid guessing answer or trial from students. Essay questions are considered as an appropriate method or a tool to assess the result of complex learning activity. It is because the writing of essay answer will involve the skill of remembering, organizing, expressing, and integrating students’ idea [20]. Essay questions will always be chosen by teachers in evaluating skill grade of students even it is not easy to give an objective assessment on each student’s answer. This form is usually used by many researchers because of its effectiveness to assess learning achievement result. It is also good to observe high-level thinking ability, such as synthesis and analysis [21]. Students' test result is analyzed by using assessment guidance. The assessment guidance on this question can be seen Table 1 [5].
Table 1. The assessment guidance for conceptual test item [5]

| Score | Level of understanding | Criteria for scoring |
|-------|------------------------|----------------------|
| 0     | No understanding (NU)  | The students did not answer, the answer did not match the question, just repeated the question, irrelevant or unclear response, no explanation given for the answer. |
| 1     | Specific Misconception (SM) | The students replied, but scientifically incorrect responses |
| 2     | Partial Understanding with a Specific Misconception (PUSM) | The students’ answer show understanding of the concept, but there are misconceptions |
| 3     | Partial Understanding (PU) | The students’ answer contains a part of scientifically accepted concept |
| 4     | Sound Understanding (SU) | The students’ answer contains all parts of the scientifically accepted concept. |

Table 1 is used as a guide in assessing students’ answers, therefore teachers can be described students’ conceptual understanding level on heat and temperature. The analysis result of students’ conceptual understanding level is listed in Table 2.

Table 2. Level of students’ conceptual understanding of heat and temperature

| Level of understanding | Percentage (%) |
|------------------------|----------------|
| No understanding (NU)  | 10.94          |
| Specific Misconception (SM) | 17.40     |
| Partial Understanding with a Specific Misconception (PUSM) | 28.85 |
| Partial Understanding (PU) | 21.67         |
| Sound Understanding (SU) | 21.14         |

Table 2 shows an overview of students’ conceptual understanding level of 10th-grade students on heat and temperature. Based on Table 2, the biggest percentage of students' conceptual understanding is on the level of PUSM or partial understanding with a specific misconception. It shows that students can only understand a part of scientific concept correctly so that they still face misconception. It is also because students tend to memorize than understand the concept. Besides concept understanding data of 96 students, another data is obtained from conceptual understanding level for each question item. Data can be seen in Table 3.

Table 3. Level of students’ conceptual understanding on each question

| Number of question | NU (%) | SM (%) | PUSM (%) | PU (%) | SU (%) |
|-------------------|--------|--------|----------|--------|--------|
| 1                 | 0.00   | 11.46  | 47.92    | 39.58  | 1.04   |
| 2                 | 28.13  | 6.25   | 13.54    | 10.42  | 41.67  |
| 3                 | 31.25  | 0.00   | 5.21     | 26.04  | 37.50  |
| 4                 | 0.00   | 1.04   | 18.75    | 5.21   | 75.00  |
| 5                 | 2.08   | 6.25   | 21.88    | 23.96  | 45.83  |
| 6                 | 2.08   | 6.25   | 75.00    | 10.42  | 6.25   |
| 7                 | 10.42  | 69.79  | 19.79    | 0.00   | 0.00   |
| 8                 | 14.58  | 7.29   | 64.58    | 12.50  | 1.04   |
| 9                 | 10.42  | 59.38  | 7.29     | 22.92  | 0.00   |
| 10                | 10.42  | 6.25   | 14.58    | 65.63  | 3.13   |
Table 3 shows the level of students' conceptual understanding on each question. Based on the data from Table 3, it can be seen that the biggest percentage of students' conceptual understanding of each number is various. However, most of them are dominated on the level SM (specific misconception) and level PUSM (partial understanding with a specific misconception), teachers must concern on this matter because many students still face misconception. The graphic of level students’ conceptual understanding of each question is shown in Figure 1.

![Figure 1](image.png)

**Figure 1.** Level of students’ conceptual understanding on each question

Based on figure 1, level NU (no understanding) is the biggest at number 3. Number 3 contains expansion concept in the making of the thermometer. In this question, students are asked to analyze if thermometer glass has the same coefficient as alcohol on the expanded space. Expansion concept is one of the concepts that are often used in daily life. However, many students can not answer it at all.

On level SM (Specific misconception), the biggest percentage at number 7. The question is about the influence of thermal conductivity value of the material. In this question, students are asked to determine which objects are cooler if it is touched. The three objects (glass, wood, and iron) have the same temperature at the beginning. Most of the students answer that the condition is because of the influence of specific heat. The example of students' answer can be seen in Figure 2.

![Figure 2](image.png)

**Figure 2.** The example of student's answer that makes mistakes at number 7.

Besides students' mistake in answering the question at picture 4, the students were still carried on with the previous concept in junior high school, that the objects were distinguished into conductors and isolators regardless of the magnitude of the thermal conductivity value of each object. Students still assume if the isolators object has a zero thermal conductivity value or no thermal conductivity value. Students' answer can be seen in Figure 3.

![Figure 3](image.png)

**Figure 3.** The example of student's answer that makes mistakes at number 7.
Students’ answers are not entirely wrong, but wood and glass also have thermal conductivity values even though they are not as big as the thermal conductivity of iron. The object is cold when it is touched because heat transfer from hand to object. The ability of objects to transferring heat is influenced by thermal conductivity value of the material. Students still relate the concept of thermal conductivity with cold/hot objects. Students also find difficulty in differentiating thermal conductivity concept and specific heat concept [22].

The low of students’ conceptual understanding because of problem type from teachers only about the mathematic problem. Exercises and example from teachers focused on the mathematic problem, so students only have the algorithmic understanding. Algorithmic understanding is students' understanding of the mathematic problem. The example of students' answer on the mathematic problem about thermal conductivity concept can be seen in Figure 4.

![Figure 4](image)

**Figure 4.** The example of students’ answer on mathematic problem

Conventional teaching learning process stressed in the mathematic problem, therefore when students are given conceptual problem, students can not be able to answer it as seen in figure 3. Sometimes, many students can answer the question correctly, but they cannot provide the reasons that support the answer. The result showed that students were able to use formulas and solve mathematical problems, but they did not understand the underlying concepts of the formula [23].

On level PUSM (partial understanding with a specific misconception) shows students' answer that understands a scientific concept, but there is still a misconception. On level PUSM, the biggest percentage at number 6. In this question, students are asked to compare two conditions and to determine which one that has bigger heat energy. In this question, most of the students confuse to answer because students’ habit of solving the problem of physics with mathematic calculation. The mathematic calculation can create answer or conclusion, but students’ skill to analyze is still low. Students' answer can be seen in Figure 5.

![Figure 5](image)

**Figure 5.** The example of wrong students’ answer at number 6.
Based on Figure 5, it can be seen that students still find difficulty in analyzing the relation among variables. Many students have conceptions that amount of heat energy depend on the temperature of the object because students viewed that higher temperature objects would have more heat energy [24]. It is appropriate with the result of students’ interview. Students state that there is difficulty in analyzing the relation among the number of heat, mass, specific heat and temperature addition. Nevertheless, there are students who understand the concept of the relationship between mass, specific heat and temperature addition. The example of students’ answer can be seen in Figure 6.

![Figure 6](image-url)

**Figure 6.** The example of correct students’ answer at number 6.

Based on the interview, almost of the student said that difficulty solves number 6 because mass and heat specific not listed in the question. Student prefers counting than applying the concept to solve the problem. The ability of students to complete a mathematic problem (algorithmic) does not depend on the students’ conceptual understanding. Based on that statement, students may be able to complete algorithmic question correctly, but they don't understand the basic concept correctly [25]. Problem type from the teacher only about the mathematic problem. The example of students’ answer about heat energy based on problem type from the teacher can be seen in Figure 7.

![Figure 7](image-url)

**Figure 7.** The example of students’ answer about the mathematic problem.

Based on Figure 7 students can solve the mathematic problem and calculate heat energy, but based on Figure 5, students still confuse to explain the relation of mass and temperature. The low of students’ conceptual understanding in analyzing the relationship between mass and heat is also revealed by the previous researchers. Students think that temperature of an object depends on the mass, in which if there is a big mass, so it also has big temperature and vice versa [26, 27]. If there is small mass, the heat to be absorbed is greater so that the temperature will increase quickly [28]. Students assume that the heat of an object is related to the heat received by the object, so students spontaneously answer that objects with the big specific heat will become hot quickly [29]. Students can use the equation \( Q = mc\Delta T \) to determine the amount of heat, but students are unable to connect the four quantity in the equation [23].

The difference of students’ conception is influenced by many factors. One of them because the different prior knowledge owned by students. The difference of students’ conception is because students come to the class with different knowledge, a knowledge built from daily life. Students’
knowledge of the concept of heat and temperature comes from daily life. The concept of heat and temperature directly related to the environment and daily life. Therefore, heat and temperature cannot be directly observed [30]. Students come with various impressions and concepts that come from their life. Many impressions and concepts might be wrong [31].

On level PU (partial understanding), the biggest percentage is at question number 10. This question is about the concept application of the Black principle to determine the specific heat of the material. Students are required to design experimental procedure with tools and materials mentioned in the question for the experiment purpose to be achieved. In this question generally, students have not been able to answer the steps in order to determine the specific heat of the metal. Besides that, many students have not understood the usefulness of calorimeters and steps to determine specific heat. Students only know Black principle, but they are unable to apply it to measure specific heat of the metal. Based on the interview result, students are difficult to answer the question because they have never conducted a lab work.

Students have difficulties in distinguishing between Q released and Q received. Many students are confused about the concept of heat and temperature. Temperature perception is only about hot and cold and temperature can be transferred. Students memorize this concept and cannot make any relation between knowledge and physics phenomenon in their daily life [32].

On level SU (sound understanding), shows students’ answer that understands a true and complete scientific concept. The lowest percentage is at number 7 and 9. Number 7 has been discussed on level SM (specific misconception), while number 9 concerns about the concept of the heat capacity of the material. In this question, students are asked to analyze the cause of how an object cools fastly if there are two objects that cooled with the same source and at the same time.

At number 7 and 9, students are difficult in differentiating specific heat concept, heat capacity, and thermal conductivity. Most of the students still consider that the cause of how objects cool fastly at number 9 is the influence of specific heat of an object. At number 7, students consider that specific heat is a factor that influences the fast on how heat is absorbed by an object. The example of students’ answer that finds difficulty at number 9 can be seen in Figure 8.

![Figure 8](image.png)

**Figure 8.** The example of student's answer that makes mistakes at number 9

Heat capacity becomes one of important concept on heat and temperature. Students can calculate the heat capacity, but they don’t know the effect of the heat capacity of the material. Based on students' answer in the mathematic problem from the teacher, almost all students can calculate the heat capacity, but not understand the basic concept of heat capacity. The students' answer to the mathematic problem on heat capacity can be seen in Figure 9.

![Figure 9](image.png)

**Figure 9.** The example of students' answer about the mathematic problem.
The low of the conceptual understanding is because teachers’ learning method focused on giving formula or mathematic formulation than the conceptual problem, therefore makes students didn’t understand the concept. Students' mathematics ability more dominant than students' perception, so it caused the wrong conception. The integration of mathematics ability and students' perception in physics can decrease the wrong conception [33]. The low of the understanding of heat capacity concept is revealed by the previous researcher that states if the heat capacity is big, the temperature of an object will increase quickly [34]. Another study revealed that students do not consider the value of specific heat and heat capacity as a factor that influences temperature changing [23].

Conceptual understanding of heat and temperature is still low due to the concept of heat and temperature closely related to the daily life of students. One of the main discussions in science education is conceptual understanding and students' misconception of heat and temperature. The main reason for this concern is a fact that heat and temperature are two common words in students' life. This conceptual understanding is a key to understanding other scientific concepts. It is also important for science teachers to understand students’ knowledge about this concept and to develop new curriculum and teaching methods for science class [35].

Based on the results of interviews with students, teachers have not used a scientific approach to physics learning. Teachers still use lecture methods with PowerPoint presentation media. So, the concept of physics is less embedded. Teaching with PowerPoint media presentation make teacher tend to omit to ask questions or discussion with students, this is noticed that many science students are relatively shy. In such situations, they would move their eyes from screen to textbook. Thus the instruction would become a monolog of the teacher. Although the PowerPoint presentation has disadvantages, it also has advantages in producing better visual effects and deeper impression [36].

The low of students' conceptual understanding can emerge misconception. A study aimed at identifying students’ misunderstanding that emerges misconception on heat and temperature concept. The result of the study indicates that students have difficulty in connecting knowledge gained during at school with experience in daily life. Students’ misconception occurs because there is no relation between daily life with school experience [37].

One of the efforts to decrease students’ misconception is that teachers must know the level of students' conceptual understanding. Therefore, it needs profile analysis of the level of students' conceptual understanding of heat and temperature. Students’ profile can support information media owned by teachers to know how far the difficulty and indicators that have been achieved by students [38]. Teachers must also be able to conduct an analysis of learning indicator achievement. Profile analysis of students' conceptual understanding level is made assisted by software Microsoft Excel. Analysis of students’ profile using Microsoft Excel is developed by research from Wulandari, et al. (2015).

Profile analysis of students' conceptual understanding level with Microsoft Excel only needs a simple formula to get the profile for each student. Answer keys, students’ answer and indicator on each question are processed into Microsoft Excel to get students' conceptual understanding level. The example of the profile of students' conceptual understanding level can be seen in Figure 10.

Figure 10 shows the profile of students' conceptual understanding level. At Figure 10 shows the indicators that have been achieved and have not. Besides that, it also shows the students' conceptual understanding level on each number and the percentage achievement of conceptual understanding level on each student. Students’ profile can also be used to know students’ learning achievement and to find students’ difficulty on physics material.
### Students' Profile

| Student Identity | Indicator | Not yet achieved | Concept understanding level |
|------------------|-----------|------------------|-----------------------------|
|                  | Number | Score | Achieved |                                      |                                      |
|                  | 1      | 3     | Being able to determine the thermometer exactly, but do not give the reason for the selection of a thermometer. | Determine the reason for selecting the right thermometer based on the properties of the thermometer filler liquid. | PU |
|                  | 2      | 0     | -        | Determine the reason for the use of capillary pipe in thermometers accordance with the correct concept completely. | NU |
|                  | 3      | 0     | -        | Explain the consequences if the coefficient of expansion of the glass chamber of the thermometer is the same as the thermometer filler according to the correct concept completely. | NU |
|                  | 4      | 4     | Being able to explain the concept of expansion based on problems in daily life according to the correct concept completely. | Explain the cause of the phase change in everyday life according to the correct concept. | SU |
|                  | 5      | 2     | Being able to explain the cause of the phase change in daily life, but still contain misconceptions. | | PUSM |
|                  | 6      | 2     | Being able to calculate and explain the heat energy based on the experiment, but there is still a concept error (misconceptions). | Calculates and explains the heat energy based on the experiment according to the correct concept. | PUSM |
|                  | 7      | 1     | Being able to answer, but not in accordance with the correct scientific concept (misconception). | Apply the concept of the effect of thermal conductivity of materials on heat conductivity according to the correct concept based on experimental data. | SM |
|                  | 8      | 1     | Being able to answer, but not in accordance with the correct scientific concept (misconception). | Compare two experiments that absorb more heat energy according to the correct concept. | SM |
|                  | 9      | 0     | -        | Determine the effect of specific heat and heat capacity of the object on the amount of heat absorbed according to the correct concept completely. | NU |
|                  | 10     | 2     | Being able to design an experiment to determine the specific heat of a material according to the correct concept, but there is a misconception. | Designing an experiment to determine the specific heat of object according to the correct concept. | PUSM |

| The percentage of concept understanding level | Percentage |
|---------------------------------------------|------------|
| NU                                          | 30%        |
| SM                                          | 20%        |
| PUSM                                        | 30%        |
| PU                                          | 10%        |
| SU                                          | 10%        |

**Figure 10.** The display of students’ conceptual understanding profile

### 4. Conclusion

Based on the result and the data analysis, students’ conceptual understanding level of 10\textsuperscript{th} grade students on heat and temperature is as follows: (1) Most students have conceptual understanding level at partial understanding with a specific misconception (PUSM) with percentage 28.85%; (2) Most students are able to solve mathematic problem from teacher, but don’t understand the underlying concept.

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