Students’ profile of heat and temperature using HTCE in undergraduate physics

Dewanta Arya Nugrah¹, A. Suparmi², Retno Winarni³, Suciati⁴
¹, ⁴ Science Education, Graduate Program, Faculty of Teacher Training and Education, Universitas Sebelas Maret
² Physics Department, Graduate Program, Universitas Sebelas Maret
³ Primary School Teacher Education Department (PGSD), Faculty of Teacher Training and Education, Universitas Sebelas Maret

Email: dewanta.an@gmail.com

Abstract. Understanding heat and temperature are important to make strong fundamental of physics before understanding the other subject materials. This research aims to describe the students’ conception of heat and temperature using Heat and Temperature Conceptual Evaluation (HTCE) developed by Thornton and Sokoloff. This research subjects are 10 students of 3rd semester and 24 students of 5th semester Bachelor of Physics. The data collection methods are test and interview. The result are the students’ conception of heat and temperature, rate of cooling, calorimetry, rate of heat transfer, perception of hotness, specific heat capacity, change of phase, thermal conductivity. Students are getting difficult on understanding the concept of heat and temperature especially the concept of rate of cooling, change of phase, and rate of heat transfer. The average students’ correct answer is 44.88% of 34 students. The lowest mean score is the concept of RHT with the percentage of 17.65%. This research could be used to develop learning media on basic physics course.

1. Introduction

The aim of some physics education research is to study students’ understanding or conception in physics using standardized test. Example of the well known standardized tests are Force and Motion Conceptual Evaluation (FMCE) [1], Force Concept Inventory (FCI) [2], Thermal Concept Evaluation (TCE) [3], and Heat and Temperature Conceptual Evaluation (HTCE) [4]. In this study, we focus on the survey using HTCE. Heat and temperature are one of fundamental of physics topic on basic physics course. Heat and temperature are subject matter which contains abstract concept [5]. The studies have done about student understanding show that students get some difficulties in understanding and explaining the heat and temperature concept. The studies about it have been done by Tanahoung, et al.[6], Carlton [7], Yeo and Zadnik [8], Budiarti, et al. [9].

Understanding the concept should be emphasized in the learning because with the understanding of the concept students can understand the whole of the main material on the matter of heat and temperature. Baser states from the point of view of constructivism learning, new knowledge is constructed with existing knowledge [10]. Therefore one of the factors in learning is the initial knowledge, usually an alternative conception of the topic. Thus it can be said that the initial
understanding of students before learning also affects the understanding of student concepts after learning. Therefore, the survey conducted to find out the students' understanding of heat and temperature.

2. Method
This research method of this preliminary study is descriptive survey method. The data collection are using test and interview. The subjects of this research are 10 students of 3rd semester and 24 students of 5th semester year 2016/2017, Bachelor of Physics, Faculty of Mathematics and Natural Sciences Universitas Sebelas Maret. The test is using HTCE [4], s consist of 27 multiple choice questions with the short reasons. After students doing the test, the researcher gives some interview to get deep information about the answer. The results from the test are divided based on the categories of concept of HTCE as shown in table 1.

| Conceptual areas                  | Question Number |
|-----------------------------------|-----------------|
| 1. Heat and temperature (H&T)     | 1, 2, 3, 4      |
| 2. Rate of cooling (COOL)         | 5, 6, 7         |
| 3. Calorimetry (CAL)              | 8, 9            |
| 4. Rate of heat transfer (RHT)     | 10, 11          |
| 5. Perception of hotness (HOT)    | 12, 13, 14, 15  |
| 6. Specific heat capacity (CAP)   | 16, 17, 18, 19  |
| 7. Change of phase (PHASE)        | 20, 21, 22, 23, 25 |
| 8. Thermal conductivity (COND)    | 26, 27, 28      |

3. Results
HTCE was tested to students of bachelor physics who have studied about heat and temperature before. The results of the test using HTCE for the students are the truth and wrong answer. 44.88% of 34 students could answer the question correctly. The percentage of the correct answers are shown on figure 1. From figure 1 we can get the three

![Figure 1. Students mean scores in each conceptual area](image)

Based on Figure 1, The result showed that the students still get some difficulties to understand the concept of rate of cooling, change of phase, and rate of heat transfer. The highest score is in heat and
temperature concept with the percentage of 59.56%. The lowest mean score is the concept of RHT (question number 10 and 11) with percentage of 17.65%. More than 50% students get some difficulties on concept of CAP, PHASE, COOL, and RHT.

The 3rd of the most difficult concept is about PHASE. Figure 1 shows that only 34.12% student who can answer the question correctly. The PHASE concept consist of 5 questions, with the question number 20 is the most of student answer false. The students’ answer is presented on table 2. Most of the students do not understand the concept of the temperature change during the time (question 20-23). Question 20 – 23 ask about the graph of the change of phase (see figure 2 for question number 20). In these question some students think that when the ice is melting and water is boiling the temperature will change and the energy is used to change the phase and the temperature. It means that the students do not understand the concept. The right answer is the energy only used to change the phase until the ice of water change totally and the energy will change the temperature when the ice or water finished to change the phase. Question number 25 is about the temperature of boiling water on the stove. And the students answer still shows the same perception like the previous question.

**Table 2. Students answer about change of phase concept (34 students)**

| Question | A | B | C | D | E | F | H |
|----------|---|---|---|---|---|---|---|
| 20       | 4 | 9 | 1 | 3 | 1 | 9 | 7 |
| 21       | 4 | 11| 3 | 1 | 2 | 4 | 9 |
| 22       | 0 | 0 | 3 | 10| 6 | 6 | 9 |
| 23       | 0 | 3 | 2 | 5 | 1 | 15| 8 |
| 25       | 1 | 4 | 9 | 13| - | - | 7 |

The key answer

![Figure 2. Question Number 20](image)
The concept of the rate of cooling is the 2nd most difficult concept answer by students, with only 34.31% can answer it. This concept consists of 3 questions (question number 5, 6, 7). From the question 5 (figure 3), it shows that student can’t determine the rate of cooling, but at question 6 (figure 4) most students can answer it. It means that students just answer by their feeling (intuition) without understanding the concept of rate of cooling. Some students said that they choose B on question 5 because the initial temperature is lower than A, but they do not realize that the question is about the rate not about the time to reach the room temperature. Most of the students think that the question 5 and 6 ask the same thing (temperature), so they just think about the time to reach the room temperature.

### Table 3. Students answer about rate of cooling concept (34 students)

| Question | A | B | C | D |
|----------|---|---|---|---|
| 5        | 6 | 24| 2 | 2 |
| 6        | 7 | 20| 1 | 6 |

The key answer

Questions 5-7 refer to two identical cups, A and B, each containing 100 grams of water. The cups are in a room where the temperature is 25 °C. The water in cup A is initially at 55°C, while that in cup B is initially at 40°C.

5) B

**Figure 3. Question Number 5-7 [4]**

From figure 4 we know that student perception is when the heat transfer energy is smaller, it has the faster rate, but in fact, faster rate means the heat energy transfer during the time is bigger. It shows that students are unable to distinguish the heat transfer and the rate of heat transfer (in this case for cooling). In question 6, most of the students answer the right answer B, but some students still answer A because they think that cup A has the higher temperature with the higher energy. They think that with higher energy, the temperature will cooling fast without thinking that the question focuses on the quickness (time period).

Most students cannot answer correctly on the question about rate of heat transfer concept. In this concept, the percentage of student who can answer the question correctly is 17.65%, this concept is the...
same concept which is the lowest correct answer on the research done by Tanahoung [6]. In this concept there are 2 questions (question 10 and 11). Actually, the concept is like the concept of rate of cooling but, here focus on heat transfer to maintain the temperature of water. To answer the question students must understand the concept of rate of heat. 12 students answer H (none of the above answers is correct). They answer H because they think that the information given in the question doesn’t complete. The said that there’s no information mass and the areas of heater that in touch with the water. In this case, it shows that student unable to analyze the rate of heat transfer because there is not enough information. Actually, when they want to calculate they can eliminate the mass and areas because when they find the comparison, they can ignore the mass and the areas (it’s the same amount). 7 students answer C because they think that the temperature to maintain in A is higher than the temperature in B, so the rate will be faster. Some students only think that the rate of heat at A is faster than B without calculating the rate of heat because the information doesn’t enough (see figure 6).

**Table 4. Students answer about rate of heat transfer concept (34 students)**

| Question | A | B | C | D | E | F | G | H |
|----------|---|---|---|---|---|---|---|---|
| 10       | 2 | 8 | 7 | 2 | 0 | 2 | 1 | 12|
| 11       | 4 | 4 | 6 | 4 | 0 | 1 | 2 | 13|

- The key answer

**Figure 5. Question Number 10 [4]**

**Figure 6. Example of students’ incorrect answer of question 10**
4. Conclusion
From the results, we can conclude that students getting difficult on understanding the concept of heat and temperature especially concept of rate of cooling, change of phase, and rate of heat transfer. The average students’ correct answer is 44.88% of 34 students. The lowest mean score is in the concept of RHT students getting difficult on understanding the concept of heat and temperature especially concept of rate of cooling, change of phase, and rate of heat transfer with the percentage of 17.65%. Most of the students still get some difficulties to distinguish rate of heat or rate of cooling with the time needed. Overall of this result, the misconception needed to be corrected. This research could be used to develop learning media on basic physics course.

References
[1] R. K. Thornton and D. R. Sokoloff, 1998 “Assessing student learning of Newton’s laws: The Force and Motion Conceptual Evaluation and the Evaluation of Active Learning Laboratory and Lecture Curricula Assessing student learning of Newton’s laws: The Force and Motion Conceptual Evaluation an,” vol. 66, no. 4, pp. 338–352.
[2] D. Hestenes, M. Wells, and G. Swackhamer, 1992 “Force Concept Inventory,” vol. 30, no. March, pp. 141–158.
[3] P. Wattanakasiwich, P. Taleab, M. D. Sharma, and I. D. Johnston, 2013 “Development and Implementation of a Conceptual Survey in Thermodynamics,” Int. J. Innov. Sci. Math. Educ., vol. 21, no. 1, pp. 29–53.
[4] R. K. Thorton and D. K. Sokoloff, “Heat and Temperature Conceptual Evaluation,” physport.org, 2001. [Online]. Available: https://www.physport.org/assessments/assessment.cfm?I=16&A=HTCE. [Accessed: 28-Dec-2015].
[5] D. A. Nugraha, S. Suparmi, M. Masykuri, and C. Cari, 2016 “Survei Pemahaman Mahasiswa Fisika Pada Materi Kalor Dan Temperatur,” Pros. SNPF (Seminar Nas. Pendidik. Fis., pp. 24–28.
[6] C. Tanahoung, R. Chitaree, and C. Soankwan, 2008 “Surveying introductory physics students’ understanding of heat and temperature,” THAI J. Phys., vol. 165, pp. 165–166.
[7] K. Carlton, 2000 “Teaching about heat and temperature,” Phys. Educ., vol. 35, no. 2, p. 101.
[8] S. Yeo and M. Zadnik, 2001 “Introductory thermal concept evaluation: Assessing students’ understanding,” Phys. Teach., vol. 39, pp. 496–504.
[9] I. S. Budiarti, Suparmi, Sarwanto, and Harjana, 2017 “Students’ conceptual understanding consistency of heat and temperature,” J. Phys. Conf. Ser., vol. 795, p. 12051.
[10] M. Baser, 2006 “Effect of Conceptual Change Oriented Instruction on Students’ Understanding of Heat and Temperature Concepts,” J. Maltese Educ. Res., vol. 4, no. 1, pp. 64–79.