Analyzes of students’ higher-order thinking skills of heat and temperature concept

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Abstract. High order thinking skills refer to three highest domains of the revised Bloom Taxonomy. The aims of the research were to analyze the student’s higher-order thinking skills of heat and temperature concept. The samples were taken by purposive random sampling technique consisted of 85 high school students from 3 senior high schools in Jayapura city. The descriptive qualitative method was employed in this study. The data were collected by using tests and interviews regarding the subject matters of heat and temperature. Based on the results of data analysis, it was concluded that 68.24% of the students have a high order thinking skills in the analysis, 3.53% of the students have a high order thinking skills in evaluating, and 0% of the students have a high order thinking skills in creation.

1. Introduction
Students’ capability to be successful in their learning counts a lot on thinking skills. These skills are major in supporting them to solve problems during the learning process. Possessing learning skills, students can develop their cognitive intelligence and ability to relate facts or information by using their knowledge to hence a prediction on a formulated final result.

Thinking skills are not only to define. Thinking is a high order of intellectual or cognitive process [1]. Thinking ability is skill and power to be pervaded in all subjects to improve students’ performance and reduce weakness [2]. Teaching and learning activities should involve explicit thinking skills which contribute ease to categorize thinking skills based on the existing framework [3]. High order of thinking has a characteristic to solve special problems and the solutions are results of thinking and reasoning [4]. Characteristics of mental activity derived from the high order of thinking process often involve complex thinking, non-algorithmic, independence in the thinking process and can result in applicative solutions [5], [6], [7]. When one is in any unusual situations, faces plenty of problems, among alternatives and has to decide [8].

The concept of heat and temperature is studied by students from elementary school to college. Temperature is related to the amount of heat. Students had difficulties in Black Principle as two different objects of temperature touch each other, and finally, experience thermal equilibrium, so the temperature will eventually be the same [9]. Most students can not differentiate between heat and temperature [10]. Concepts related to heat and temperature are directly related to living organisms, so that heat and temperature cannot be observed directly in quantity. Concepts developed by students, derived from the interpretation of student ideas in everyday life [11].
High order thinking skills in this research refer to three highest domains of the revised Bloom Taxonomy. Three highest cognitive domains of Bloom Taxonomy (analysis, evaluation, and creation) require high order thinking skills [12]. Based on underlying theories and research objectives in the field, the researcher had performed researchers to analyze high order thinking skills on Heat and Temperature. Meanwhile, ‘how are students’ high order thinking skills of Heat and Temperature Concept?’ is stated as problem formulation in this research.

2. Research Method

The method used in this research is descriptive, to analyze students’ high order thinking skills of heat and temperature concept. Samples were taken by using purposive random sampling from 3 Senior High School (SHS) in Jayapura city. Data were collected by applying purposive multiple choice tests and interviews. The tests were adapted from HTCE (Heat and Temperature Concept Evaluation) [13]. The tests consisted of 15 numbers. Five numbers were problems of temperature, five numbers of heat and the rest are of heat transfer. Interviews were taken to collect data about reasons having been written by students.

3. Result and Discussion

Percentage of student’s conceptual understanding consistency is based on students’ answers as seen on table 1.

| High Order Thinking Skills | Percentage (%) |
|----------------------------|----------------|
|                            | SMAN 1 Jayapura | SMA YPK | SMA Pembangunan V Yappis | Average |
| Analysis                   | 75             | 66.67   | 53.33                      | 68.24   |
| Evaluation                 | 5              | 3.33    | 0                          | 3.53    |
| Creation                   | 0              | 0       | 0                          | 0       |

Based on Table 1, it can be seen that the highest domain of Bloom Taxonomy which is the highest order of high order thinking skills shows average 0%, this indicates that the students had not achieved creation stage, especially on physics concepts of temperature and heat. Table 1 also shows that students’ high order thinking skills percentage did not reach 100%, this indicates that 28.24% of students had not achieved high order thinking skills, means that 28.24% of the students were still in low order thinking skills, particularly recognized as LOTS (Lower Order Thinking Skills). Thus, there were still 28.24% of students who achieved knowledge, understanding, and application domain. After further interviews were taken, it was manifested that those three SHS applied learning method dominated by lecture method. Therefore the students were not trained to practice their high order thinking skills. High order thinking skills are achieved from student’s learning and teaching process [3].

Related to the percentage data of high order thinking skills collected from 3 SHS becoming samples of this research, the students’ high order thinking skills of temperature and heat is presented as follows:

Temperature concept

This question was the same as the problem of previous research [14]. There are glass A and B, of the same material. Glass A contains 150 gram of 60 °C water, glass B contains 150 gram of 75 °C water. Both glass A and B, are set at a room temperature of 25 °C. Which graphic best shows relation between temperature and time on glass A? (Note, the starting point does not always show 0 °C)
The problem about temperature concept above requires cognitive thinking stage from knowledge, understanding, application, analysis, evaluation, and creation. Thus the problem covers creative thinking stage. Students would be able to draw a graphic of the relation between temperature and time if the students had knowledge and understanding about temperature and heat concept. Moreover, students would also be able to apply quantities related to heat and analyze them. If the students were able to analyze the intertwined concept between temperature and heat, they would be able to evaluate it by seeking a relation between temperature and time. Heat (Q) is influenced by substance mass (m), specific heat (c), and temperature change (Δt). Heat rate (H) is influenced by heat and time (t).

\[ Q = m \times c \times \Delta t \]
\[ H = \frac{Q}{t} \]

Thus, heat rate (H) is proportional to heat (Q) and inversely proportional to time (\( \frac{1}{t} \)). By graphically drawing the relation between temperature and time, a hyperbola-shaped graph can be derived. Based on figure 1, students chose option (e), in which temperature remains the same at any time. This conclusion is also supported by the absence of reason on the answer chosen (figure 1a). After a depth interview had performed to the student, it was acknowledged that the student only recognized graphic at option (e). Thus he chose option (e). Based on figure 1a and 1b, students have the same reason. They think that the temperature remains the same at any time.

**Heat Concept**

If 150 gram of ice and 150 gram of water within the same temperature that is 0 °C are to be stored in a freezer, of under 0 °C. Left in storage until they set to the freezer temperature, which substance will lose more heat?

- a. 150 gram of ice
- b. 150 gram of water
- c. Both will lose the same amount of heat as the initial temperature was the same
- d. None is incorrect as ice doesn’t have heat quality
- e. None is incorrect as you can’t find water at 0 °C
Figure 2. Student’s answer on heat

The problem about heat concept above requires cognitive thinking stage from knowledge, understanding, application, analysis, and evaluation, thus the problem covers evaluative thinking stage. Students would be able to answer the question above if they had knowledge, understanding, and analysis of the form of matter, the process of the transformation of matter form, and heat. Students would be able to analyze two substances of different kinds and forms. If 150 gram of water within 0 °C is stored in a freezer, the water will undergo two processes, freezing (temperature 0 °C and transformation of liquid to solid takes place) and no transformation of matter form in temperature (below 0 °C) the substance will remain solid (ice). If 150 gram of ice within 0 °C is stored in a freezer, the ice will undergo one process that is temperature change (below 0 °C) with the form remains solid (ice). Heat ($Q_1$) released by water to freeze is determined by water mass ($m_a$) and melting heat (L). Heat ($Q_2$) released by water to undergo temperature change, is determined by water mass ($m$), ice-type heat ($c_{ice}$), and temperature change ($\Delta t$). Thus total heat ($Q_{tot}$) released by water is $Q_1 + Q_2 = m x L + m x c_{es} x \Delta t$. Heat released by ice, is determined by ice mass ($m_{ice}$), ice-type heat ($c_{ice}$), and temperature change ($\Delta t$). Therefore heat ($Q_3$) released by ice is $m_{ice} x c_{es} x \Delta t$. Water and ice masses are equal, thus $m = m_{ice}$. It is derived that heat released by water ($Q_{tot}$) is greater than heat released by ice ($Q_3$), or water releases more heat than ice. Based on figure 2, students did not understand the concept of temperature. Thus students could not relate the concept of temperature, the transformation of matter form and heat. The student answered that ice and water released an equal heat as the ice and water took the same initial temperature (option c). After a depth interview was taken, it was found that students did not understand the concept of form and transformation of matter form, therefore the student assumed that ice and water masses are the same, as well as their initial temperature, leading to his conclusion that ice and water released the same amount of heat (figure 2a and 2b). Based on figure 2c, the student have no reason. After a depth interview was taken, it was found that the student did not understand the concept of heat. He think that ice and water have the same of mass and initial temperature, so ice and water have the same amount of heat.

Heat Transfer Concept.

Florentina took two cartons of chocolate milk quickly, one carton was from the refrigerator, and the other was from the dining table. Why do you think the milk taken from the refrigerator was colder than the one taken from the dining table? Compare to the warm carton of milk, the cold carton of milk is………..

a. colder
b. contains more heat
c. a bad conductor
d. transfer more cold to Florentina’s hand
e. transfer more heat to Florentina’s hand
The problem about heat concept above requires cognitive thinking stage from knowledge, understanding, application, and analysis. Thus the problem covers analytical thinking stage. Students would be able to answer the question above if they had the knowledge, understanding, applicative capability, and analysis on heat concept, heat rate, and transfer. Two similar cartons of milk are in different surrounding temperature, thus the two cartons have different temperature as well. When the two cartons are quickly taken, Florentina will feel the cold milk carton taken from the refrigerator when she holds it. This happens as Florentina’s hand touches the milk carton taken from the refrigerator, heat energy from Florentina’s hand transfers to the milk carton as a result of temperature differences between hands and the milk carton. Heat is an energy flows from one substance to another which comes in contact and has different temperature. The more heat transfers from Florentina’s hand to the milk carton, the colder Florentina’s hand feels. Based on figure 3, it can be seen that students did not have an understanding of the concept of heat, and heat rate which became a basic thinking for heat transfer concept. Students answering the question only noticed from where the milk cartons were taken. After a depth interview had been taken, students revealed his argument that substance with heat is a good conductor, while the cold substance is not a good conductor (figure 3a and 3b). This finding shows that the student did not understand the flow of heat energy. Based on figure 3c, the student has no reason. After a depth interview was taken, it was found that the student did not understand the concept of heat transfer. He thinks that the cold substance is not a good conductor, so the cold substance cannot transfer of heat.

Count on table 1, it is perceivable that students’ high order thinking skills are in the analysis stage. There are 28.23% of students who are in the low order thinking skills. Referring to the depth interviews to twelve students from three SHS, eight students from two SHS testified that the teacher applied a lecture method in the process of teaching temperature and heat. Thus, the teaching model and method applied by the teacher could not support the high order thinking skills, since the students were not personally involved in the learning process. Students’ high order thinking skills can be developed or improved by model and method of teaching which support high order thinking skills.

4. Conclusion
Based on the data analysis, it is concluded that 68.24% of students achieve high order thinking skills in the analysis stage. 28.24% of students show low order thinking skills. Referring to depth interviews to twelve students from three SHS, eight students from two SHS testified that the teacher applied a lecture method in the process of teaching temperature and heat. Students’ high order thinking skills can be developed or improved by model and method of teaching which support high order thinking skills.
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