Measuring critical thinking skills of 11th grade students on temperature and heat

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Abstract. Critical thinking is one of the essential skills of 21st century learning. Therefore, students are required to have these skills to be applied in physics learning. The study aims to measure students critical thinking skills on Temperature and Heat. Participants in this study are 29 of 11th grade students (10 males and 19 females) in the city of Bandung. The instruments used are five essay questions with five different indicators. The results show that the average value obtained is 31 with less categories. The conclusion, students’ critical thinking skills on Temperature and Heat are still less. Thus, there is a need for development in the learning process to improve the critical thinking skills of 11th grade students on Temperature and Heat.

1. Introduction
Critical thinking skills are not something new in the world of education. Critical thinking has been impressed upon since the time of Francis Bacon in 1605 [1]. Several figures afterward also sought to present their theories about critical thinking, such as Edwar Glaser, John McPeck, Robert Ennis, to Peter Facione in the Reference [2]. At present critical thinking skills are incorporated into 21st century education as one of the skills that must be possessed by students [3]. Critical thinking is an activity of logical thinking in making predictions or a reasonable decision from what is believed and what has been done [4-6]. A person who thinks critically tends to see problems from many perspectives, to consider many different investigative approaches, and to generate many ideas before choosing an action [7,8]. So that students who have this skill will be easier to understand and solve problems in different situations. One of the right tools to develop the ability to think critically is to study science [9], which includes physics lessons. So, after learning physics students are expected to not only be able to master the concepts (basic thinking skills), but also have the ability to reason, think inductively, and deductively (critical thinking skills). One of the physics materials that can train critical thinking skills includes temperature and heat.

The temperature is a measure of the average kinetic energy of an internal molecule of an object, while heat is the energy transferred from an object to another object due to temperature differences [10,11]. This definition is related to the thermodynamic zero law. Thus, the temperature can be interpreted as a physics quantity possessed by two or more objects, which are at thermal equilibrium [12-14]. This concept is used on a thermometer, where the liquid in the thermometer will expand or shrink when there is a change in temperature. Furthermore, changes in temperature can also cause expansion of the metal. Examples of bi-metal plates that can be curved due to changes in temperature
and differences in the length of expansion of the two materials. If the temperature changes with \( \Delta T \), the change in length \( \Delta L \) is proportional to \( \Delta T \), the initial length \( L \), and the length expansion coefficient \( \alpha \) [13,14].

\[
\Delta L = \alpha L \Delta T
\]  

(1)

The concept of temperature and heat used to train critical thinking skills because the phenomenon can be found in everyday life. But we don’t know the extent to which students have critical thinking skills at temperature and heat. Thus, it is felt necessary to conduct a study in measuring critical thinking skills that students have on temperature and heat.

2. Methods

2.1. Participant

Subjects are students who have received temperature and heat material. Participants in this study were 29 of 11th grade students, consisting of 10 males and 19 females in the city of Bandung.

2.2. Research design

The research is a single case study with embedded design, that aims to measure the extent to which critical thinking skills students have on temperature and heat. Embedded case studies have several units, objects, analyzes and are usually not limited by qualitative analysis only [15]. Usually, most of the sub-units focus on prominent aspects only. The sub-units in this study were 11th grade students with a focus on the case of critical thinking skills. Students' thinking skills are measured through five essay tests. Students are given time 90 minutes or two hours of study to solve the problem. The results obtained were then analyzed to see the extent to which students' critical thinking skills in temperature and heat material.

2.3. Instrument

The instruments used are five essay questions with five different indicators, including elementary clarification, basic support, inference, advanced clarification, and strategy and tactics. The instrument was adopted from research related to the instrument of critical thinking skills tests at temperature and heat [16], and the instrument used was validated with a reliability value of 0.71 high category. The distribution of questions for tests of critical thinking skills is shown in Table 1 below.

| Indicators of Critical Thinking Skills | Description of Critical Thinking Skills Indicator | Number of Problems | Question Number |
|---------------------------------------|-----------------------------------------------|--------------------|-----------------|
| Elementary clarification              | Answering clarification questions              | 1                  | 1               |
| Basic support                         | Assess observation reports based on observation record criteria | 1                  | 2               |
| Inference                             | Make a value statement, based on the existence of an alternative | 1                  | 3               |
| Advanced clarification                | Assessing definition: report definition        | 1                  | 4               |
| Strategies and tactics                | Interact with others: a logical strategy       | 1                  | 5               |

The maximum value for each item is 4. The rubric sample for critical thinking skills is shown in Table 2.
Table 2. A sample of rubrics for critical thinking test.

| Indicators of Critical Thinking Skills | Question | Answer |
|---------------------------------------|----------|--------|
| Basic support observation reports based on observation record criteria | Fani made observations in simple experiments. Fani prepared three glasses each containing 80°C of hot water, 25°C of water, and cold water at 5°C with the same volume as in Figure 1. Then Fani dripped the same amount of food coloring in each glass. After 10 minutes of experimentation, Fani noted that the fastest spread of food coloring in hot water with a temperature of 80°C and the slowest in cold water with a temperature of 5°C as shown in Figure 2. | Yes, Fani’s statement is correct. Explanation of the experiments conducted by Fani It appears that there is a difference in the decrease and spread of food coloring in each glass. The decrease and spread of the fastest food coloring in a glass containing hot water and then water with room temperature while the slowest in a glass of cold water. This shows that the more heat in a substance the faster the movement of molecules in the substance. This shows that calories affect the movement of molecules in substances. |

Based on the observation notes, Fani stated “heat affects the movement of molecules in substances”. Is Fani’s statement correct? Explain your answer!

2.4. Data Analysis

Data analysis is done by calculating the values for each indicator on critical thinking skills obtained by using the formula:

\[
\text{Value} = \frac{\sum \text{score for each indicator}}{\sum \text{maximum score for each indicator}} \times 100
\]

The calculation results obtained from the above equation will be classified according to the categories contained in Table 3.

Table 3. Value Interpretation.

| Value     | Category   |
|-----------|------------|
| Value ≤ 20 | Very less  |
| 21 ≤ Value ≤ 40 | Less       |
| 41 ≤ Value ≤ 60 | Fair       |
| 61 ≤ Value ≤ 80 | Good       |
| 81 ≤ Value ≤ 100 | Very Good  |
3. Results and Discussion

The essay on critical thinking skills is distributed to 29 of 11th grade students, and all of them can be returned after students fill them out. It is known that the maximum score for each item is 4. Therefore, the total maximum score per indicator is 166, if 29 students answer correctly for the five questions about critical thinking skills, the value obtained is 100. Table 4 shows the values obtained for each indicator of critical thinking skills on temperature and heat.

Table 4. Value of critical thinking skills.

| Number | Indicator                  | Σ Score | Value | Category |
|--------|----------------------------|---------|-------|----------|
| 1      | Elementary clarification   | 28      | 24.1  | Less     |
| 2      | Basic support              | 55      | 47.4  | Fair     |
| 3      | Inference                  | 31      | 26.7  | Less     |
| 4      | Advanced clarification     | 40      | 34.5  | Less     |
| 5      | Strategies and tactics     | 26      | 22.4  | Less     |
| Average|                            |         | 31.0  | Less     |

Based on Table 4, four of the five values for each indicator critical thinking skills on temperature and heat material have a less category. The highest value is found in the indicator “Basic support” with the value obtained 47.4 in the fair category. This question is found in Table 2. Some students already have a basis used to decide what is believed and done to a statement or information.

The lowest value is in the strategies and tactics indicator with the value obtained is 22.4 in the less category. This question is related to the strategy used to solve a problem. Most students answer incorrectly, this happens because students have not been able to make a strategy in finding a solution to a problem faced.

While the other three categories, including elementary clarification, inference, and advanced clarification are also included in the less category. Elementary clarification questions relate to answers to questions from parties asking for an explanation of an argument or information submitted. Related inference questions make statements based on the existence of alternatives. Advanced classification questions are related to seeking further clarification to decide what is believed and done by assessing the definition.

Critical thinking skills are skills that must be trained in every learning process. Lack of critical thinking skills possessed by students, can be indicated because of lack of training of students for this matter. The findings in this study are relevant to research in other physical materials which states that students’ critical thinking skills are still low [17]. While the Partnership for 21st Century Skills (P21) advocated the integration of core academic knowledge, critical thinking, and social skills in teaching and learning to help students master the multidimensional abilities needed in the 21st century [18]. Then there needs to be innovation in the learning process to improve the critical thinking skills that students have.

Some learning innovations have been used to improve critical thinking skills. Among them are the application of experience-based learning models, problem-based learning, Interactive Lecture Demonstration (ILD) learning, use of learning strategies Predict Discuss Explain Observe Discuss Explain (PDEODE), and inquiry-based learning approaches. But one of the interesting learning models to note is the Attention Relevance Confidence Satisfaction (ARCS) learning model developed by Keller. This model is a motivational model [19], because according to [20] motivation is the most important factor to stimulate creativity and critical thinking. The ARCS model has also been used in research to improve critical thinking skills in other subjects such as chemistry and mathematics. So that this model can be one of the references for further research in improving critical thinking skills in physics.

4. Conclusion

Based on the results of research that has been done, seen in each indicator value obtained, only the basic support is included in the fair category. While four other indicators including elementary clarification, inference, and advanced clarification in the less category. The average score for the five indicators of
critical thinking skills is 31 of the maximum value of 100. This value indicates that the critical thinking skills possessed by students fall into the less category. Thus, there needs to be an effort to improve the critical thinking skills possessed by students, to meet the challenges of the 21st century. One effort that can be done is to apply a learning model that can improve these skills, and students can maximize their thinking skills, one of which is critical thinking skills.

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