Students’ critical thinking skills toward analyzing argumentation on heat conductivity concept

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Abstract. We have already probed students’ critical thinking skills toward analyzing argumentation on heat conductivity concept. Analyzing argumentation is needed to investigated because students require to obtain it in order to become a better thinker and making the right decisions. The heat conductivity problem has been given to 20 preservice physics students who have been enrolled in the Introductory Physics I. The test has precisely analyzed in qualitative way. An analysis of collected data has mainly focused on student conclusion in heat conductivity problem. Based on data analysis, it can be concluded that students’ critical thinking skills toward analyzing argumentation on heat conductivity concept is still poor category.

1. Introduction

Critical thinking skills have always been a primary goal of education [1]. Ennis stated that critical thinking is logical and reflective thinking driven on definite what to believe or do. Become better in critical thinking skills will not develop on their own, students must be taught. Enhancing critical thinking takes much time to organize and hard to design [2]. Therefore, a teacher must commit to developing decision making through teaching critical thinking skills [3]. In term of focusing our teaching, we have to start to know where we focus. Test of critical thinking skills is able to use in this matter by displaying specific areas of potency and limitation [4]. Most previous critical thinking research addressed in the context in which general critical thinking skills were taught separately from regular subject matter domains [5,6]. Recently, Lawson [7] stated that critical thinking development has shifted mainly toward embedding critical thinking skills within subject matter instruction in various specific domains and facilitates students’ transfer to other problem in daily life.

Argument analysis has been linked to everyday experience problem. Pascarella, Lawson, and Govier [8,9,10] stated that argument analysis is one important aspect of critical thinking skills. To construct an argument is need to think critically. What students may do before argue is critical thinking. Critical thinking has always been represented as argument [8]. Analyze argumentation is able to enhance critical thinking skills [11,12,13,14]. Identify conclusions is one of analyzing argument abilities being ideal critical thinkers [2]. A crucial element for increasing critical thinking ability is repeated exercise in making decisions based on data [15]. In physics, data are consist of several concepts such as heat.

Heat concepts involve significant elementary science subject matter which students can understand and familiar to teaching critical thinking [16]. Heat is moved from the warm water to the cold water...
while waiting for both sections have the equal temperature. In this example, conduction is referred to the transfer of heat from the hot water through the metal can to the cold water [17]. Conductive heat drift includes the transfer of heat from one place to another in the non-appearance of any substantial flow. The thermal conductivity formula has been stated below.

\[ k = \frac{QL}{A\Delta T} \]  

There is nothing physical or material moving from the hot water to the cold water. Only energy is transferred from the hot water to the cold water. Heat as one form of energies is very crucial to be learned by pre-service physics teacher because the topic applicable to constructivist approach and can relate it to daily life. Heat conceptions developed by students initiated from the clarification of thoughts expanded from daily experiences. In addition, beliefs and linguistics are the capable aspects of rising concepts connected to heat and temperature [18,19].

Heat conductivity concept is many found in the daily life phenomena. Critical thinking skills have mainly been linked to daily life problems. To the best of our knowledge, there is no available critical thinking test related to only one aspect of critical thinking about analyzing argumentation on heat conductivity concept. The aim of this research is to investigate preservice physics students’ critical thinking skills toward analyzing argumentation on heat conductivity concept.

2. Method
Participants who were involved in this research were 20 undergraduate students (4 male and 16 female, whose aged were around 20 years old). They were originated from different towns and enrolled in introductory physics I courses. The research was accompanied in the first semester of the academic year 2017/2018 at the Programme of Physics Education in Universitas Tadulako. The participants are identified using essay test questions on heat conductivity concept. Heat conductivity concept was chosen because it involves significant elementary science subject matter which students can understand and familiar with teaching critical thinking [16]. Heat conductivity problem has already been analyzed by using the rubrics of critical thinking [2]. An example of heat conductivity problem is shown in figure 1.

Problem
The insulation wall is a thermal control using a building wall material with a low thermal conductivity and heat transmittance that has the capability of reducing heat transfer. The higher the thermal conductivity, the more easily the heat, so the more easily increases the temperature in space. Here is the heat conductivity of some wall materials:

| Materials    | Heat Conductivity (W/mK) |
|--------------|--------------------------|
| Concrete     | 1.13                     |
| Light Brick  | 0.5                      |
| Solid Brick  | 1.4                      |
| Marble       | 3.5                      |
| Sandstone    | 5.2                      |
| River Stone  | 2.2                      |
| Hardwood     | 0.16                     |
| Zinc         | 11.0                     |
| Plaster      | 0.9                      |
| Cement       | 1.0                      |

From the description of the argument above, identify the conclusion correctly.

**Figure 1.** Heat conductivity problem.

Researchers have been used a survey method. The essay test as an instrument has been developed and validated by the expert. The essay test is more comprehensive than the others [4]. Calculate the percentage of the score has conducted after scoring the participant responses. The formula has been stated below:

\[ \% = \frac{\text{total participant each category}}{\text{total participant in all category}} \times 100\% \]
3. Result and discussion

In terms of investigating students’ critical thinking level toward analyzing argumentation, we present at Table 1. Analysis of qualitative data has been provided sufficient evidence that this initial stage is able to a good basis for teaching critical thinking. The results have already displayed potency and limitation of students’ critical thinking abilities toward analyzing argumentation on heat conductivity concept.

Table 1. Students’ responses in each criterion

| Complete Conclusion (CC)          | Partial Conclusion (PC)          | Mistake Conclusion (WC)         |
|----------------------------------|----------------------------------|---------------------------------|
| S4, S12, S13                     | S2, S5, S7, S11, S15, S17        | S1, S3, S6, S8, S9, S10, S14, S16, S18, S19, S20 |

Note: S1, S2, S3... refer to the particular students in the research

As shown in table 1, most of the participants have precisely been classified in poor categories. This means that the students have rather difficult to conclude argumentation. The percentage of students’ responses in each criterion is shown in figure 2.

![Figure 2. Preservice physics students’ responses.](image)

Based on the data in figure 2, overall 15% of students (n = 3) have mainly been categorized as complete conclusion level. In contrast, the critical thinking skills toward analyzing argumentation for 11 students (55%) have been categorized as mistake conclusion category and for 6 students (30%) as partial conclusion category. The results have been demonstrated that a few potencies are able to improve through a systematic design of subject matter instruction in the future. The students in complete conclusion level have already concluded that the best wall material is hardwood because it has the lowest thermal conductivity and the least wall material is zinc. The diagnosing test has been shown that three students who have better performance than others as a good basis for teaching critical thinking. This finding confirms the previous studies students who achieved better in a critical thinking assessment, therefore showing higher levels of critical thinking reported fewer negative outcomes in their daily lives [20].

On the other hand, students’ performance has already been showed that overall 85% of students categorized as the mistake and partial categories. A number of reasons may explain why the critical thinking test did not give satisfying results. For the first, students have failed to think comprehensively. They have focused only on previous sentences and they have failed related the previous sentences to the data on the table. For instance, S2 has been concluded that high conductivity material will be easy to deliver heat but he did not relate it to the given table in the question. Most students could not conclude that hardwood is the best material using for reducing heat transfer and zinc is the worst one. For the second, the lack of students’ analyzing argumentation skills have mainly caused by the students are not
accustomed to solving critical thinking test and facing the conceptual problem. A few examples of students’ mistake conclusion on heat conductivity argumentation are detail presented in Table 2.

Table 2. A few examples of mistake conclusion of students responses on heat conductivity problem based on table 1.

| An examples of students’ conclusions |
|--------------------------------------|
| S1 Zinc is a material with the highest thermal conductivity that can help the insulation wall process. |
| S3 Marble has the greatest heat conductivity value compared to other building materials. |
| S9 Thermal conductivity is affected by both low and high temperatures. |
| S10 Zinc is a building material that has the high ability to reduce heat transfer. While light bricks are building materials that have the low ability to reduce heat transfer. |

For the third reason, many students have been confused about the concept. For example, some students have been assumed that Zinc is a material with the highest thermal conductivity that can help the insulation wall process and reduce heat transfer. This finding is consistent with the result that students may have decent conceptions but they still had troubles in connecting the scientific concepts to their proficiencies in everyday contexts [21,22]. A few examples of students’ partial conclusion on heat conductivity argumentation are detail presented in Table 3.

Table 3. A few examples of partial conclusion of students responses on heat conductivity problem based on table 1.

| An examples of students’ conclusions |
|--------------------------------------|
| S2 Materials that have high conductivity will be easy to deliver heat. Not related to the given table in the question. |
| S5 Zinc material has a higher conductivity so it is easier to increase the temperature in the room. |
| S7 Zinc is the easiest material to deliver heat due to the highest thermal conductivity value. |
| S17 Zinc is the highest thermal conductivity and the light brick has the lowest thermal conductivity. |

The last reason, students have failed to conclude the argumentation because they have a limitation in critical thinking. To analyze the argumentation, students need to think critically. Critical thinking is what students may do before argue. This finding confirm the previous studies critical thinking have always been represented as argument [8], analyze argumentation is able to enhance critical thinking skills [11,12,13,14], quality of critical thinking related to the potency of the arguments made showed that science/applied science fields reveal significantly more progressive patterns than non-science fields [23], and identify conclusions is one of analyzing argument abilities being ideal critical thinkers [2]. Based on potency and limitation of the results, teaching to enhance critical thinking takes much time to prepare and difficult to plan. Commitment is needed to developing decision making through teaching critical thinking skills [3]. This preliminary research is able to a good basis where to focus our teaching [4]. Effective teaching strategies that have positive effects on critical thinking skills is the opportunity for dialogue, coruscation to authentic or situated problems and examples [24] and embedding critical thinking skills within subject matter instruction in various specific domains and facilitate students’ transfer to other problem in daily life [7]. A constructivist approach that related to the application in daily life should be utilized to promote students’ analyze argumentation ability [25,26,27].

4. Conclusion
Overall 15% of students (n = 3) have already been categorized as complete conclusion level. In contrast, the critical thinking skills toward analyzing argumentation for 11 students (55%) have mainly been categorized as mistake conclusion category and for 6 students (30%) as partial conclusion category. The results are able to display potency and limitation of students’ critical thinking abilities toward analyzing
argumentation on heat conductivity concept. The diagnosing test have shown that three students as a good basis for teaching critical thinking. On the other hand, students’ performance has been shown that overall 85% of students categorized as the mistake and partial category. A number of reasons may explain why the critical thinking test did not give a satisfying results, consist of students have failed to think comprehensively, students have not accustomed to solving critical thinking test and facing a conceptual problem, students have been confused about the concept, and limitation in critical thinking skills.

Based on the analysis data, it can be concluded that students’ critical thinking skills toward analyzing argumentation on heat conductivity concept is still in poor categories. Constructivist approach that related to the application in daily life and opportunity for dialogue should be utilized to promote students’ analyze argumentation ability.

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