



STUDENTS' CRITICAL THINKING OF HEAT AND MATTER

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ABSTRACT

Modern technologies have shaped human lives but technologies that facilitate rapid information sharing can enable misleading information. Thus, it becomes pertinent that man should think critically when presented with daily problems information. This study explored students' critical thinking when presented with daily problems concerning heat and matter, which are prone to misunderstanding. Results suggested that students are moderately critical when presented with daily problems concerning heat and matter. The correlation between each critical thinking element is also discussed.

ABSTRAK

Teknologi modern telah membentuk kehidupan manusia tetapi teknologi yang memfasilitasi penyebaran informasi yang cepat memungkinkan adanya informasi yang menyesatkan. Dengan demikian, penting bagi manusia untuk berpikir kritis ketika dihadapkan dengan informasi mengenai masalah sehari-hari. Penelitian ini mengeksplorasi pemikiran kritis siswa ketika dihadapkan dengan masalah sehari-hari tentang panas dan materi, yang rentan terhadap kesalahpahaman. Hasil menunjukkan bahwa siswa cukup kritis ketika dihadapkan dengan masalah sehari-hari tentang panas dan materi. Korelasi antara setiap elemen berpikir kritis juga dibahas.

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INTRODUCTION

Modern technologies have shaped human lives in which 91% of people in the United States use the online platform as their source of information, with 73% of them believe most or all the information they find is accurate and trustworthy (Purcell, Brenner, and Rainie, 2012). This finding is also found worldwide, with 42% of people in 38 countries using the internet as their news and information source at least once a day (Mitchell, Simmons, Matsa, and Silver, 2018). As for South Korea, World Bank data showed that 96% of the population uses the internet, far higher than OECD countries average of 85% (World Bank, 2019). Technologies that facilitate rapid information sharing can enable the spread of misleading information, but contrary to popular belief, humans-the force behind the technologies- make false information spread faster than the truth (Vosoughi, Roy, and Aral, 2018). Study suggested that even brief exposure to misinformation can lead to long-term false memories (Zhu et al., 2011) and therefore, it becomes pertinent that man should be able to decide whether to believe something or not by thinking reasonably and reflectively (Ennis, 1985)

or defined as critical thinking skills. Critical thinking is a complex process, and if it is done well, it can help us examine complex ideas systematically to understand better both the issue and the consequences of acting on it (see Inch, Warnick, and Endres, 2006). A person who has thought critically about an issue will not settle with the apparent solutions but will suspend judgment while seeking arguments, facts, and reasons to promote sound decision-making (Inch et al., 2006).

National Research Council (NRC,2012) stated that critical skills are important for success in education, work, and other areas in adult responsibility. Further, studies also uncover the empirical proof on the correlation between critical thinking skills and academic performance (see D'Alessio, Avolio, and Charles, 2019; Ghanizadeh, 2017; Kettler, 2014; Ghazivakili et al., 2014; Ricketts and Rudd, 2005). This importance is currently represented in the curriculum across the countries, and problems in students' critical thinking skills have also been addressed (Holmes, Wieman, and Bonn, 2015; Barnett and Francis, 2012; Yang and Wu, 2012; Abrami et al., 2008; Barak, Ben-Chaim, and Zoller, 2007; Van Gelder, 2005). Unfortunately, students' critical thinking in physics is

still underrepresented in the literature. PISA results report suggested that students' average performance in understanding physical systems is the lowest among other science content subscales (OECD, 2016) and empirical studies also suggested that physics is potential area of concern. Students' understanding of physics concept such as heat and matter for example is often incorrect or incomplete (Chang and Pascua, 2016; Ozalp and Kahveci, 2015; Tsitsipis, Stamovlasis, and Papageorgiou, 2012; Mayer, 2011) and persistent to change (Prince, Vigeant, and Nottis, 2012). With such consideration, this present study evaluated students' critical thinking when dealing with daily problems related to heat and matter concept.


METHOD

Critical thinking skills evaluation participant was 117 junior high school students (7th grade students). Critical thinking skills were measured with Science Virtual Test developed based on Inch et al. (2006) as well as Paul and Elder (2007) modified critical thinking elements: purpose, the question at issue, assumption, information, concepts, and making interpretation or inference. A range of questions related to heat and matter

concepts was used to evaluate students' critical thinking skills. A question, for example, evaluates students' critical thinking of the oxidation process in Banana by presenting them with a video about spotting in Banana (Figure 1). With a total of 11 questions (valid and reliable, $\alpha = 0.642$), the questions ranged from moderate to difficult. Students' critical thinking skills were analyzed descriptively and correlations between each critical thinking element were also calculated. Students' score were also grouped within three categories: high ($X \geq \bar{X} + S_x$), moderate ($\bar{X} - S_x \leq X \leq \bar{X} + S_x$) or low ($X \leq \bar{X} - S_x$).

RESULTS AND DISCUSSION

Students' critical thinking skills average only amounted to 53.69 (SD = 21.55) or moderate. Based on score and standard deviation value, students were grouped within three categories. Among 117 students, 32.14% were considered low critical thinking skills, 53.69% were considered moderate, and only 14.17% students were considered as high critical thinking skills.




Sumber: <https://www.youtube.com/watch?v=jKCWabdj29s>

Q-10. The video raises the question, "Why do Bananas oxidize?". To uncover the answer, what is the most appropriate sub-question?

- A) Did the fruit rot?
- B) Is discoloured (browning) fruit still edible?
- C) Besides bananas, what fruits are prone to oxidation?
- D) How long does the oxidation process take in fruit?

Figure 1. Science Virtual Test Question Example: Oxidation Process



Q-5. Based on the video, rainbow shaved ice consisted of several types of chopped fruits, cheese, and ice. What concept related to this situation?

A) Element, because it is a material that cannot be divided again
 B) Compounds, because they are made of more than one different material with a fixed composition
 C) Homogeneous mixture, because it is made of different materials and is physically united
 D) Heterogeneous mixture, because it is made of different materials and is physically separated

Figure 2. Science Virtual Test Question Example: Mixture

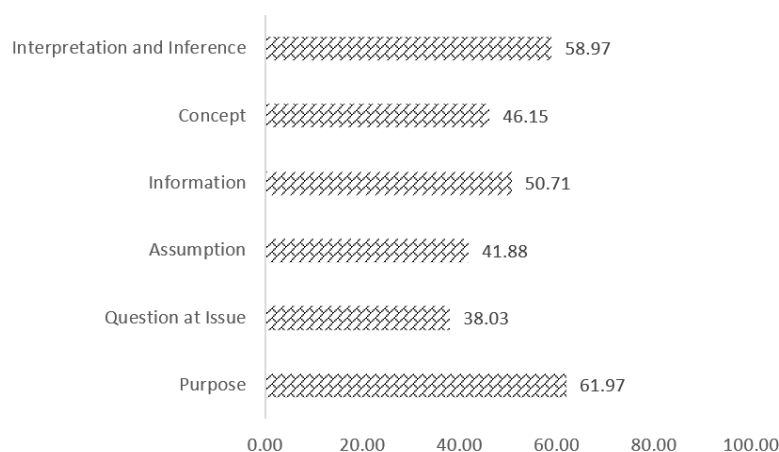


Figure 3. Students' Critical Thinking Skills in Each Critical Thinking Skills Elements

Table 1. Correlation Between Each Critical Thinking Skills Elements

	Purpose	Question at Issue	Assumption	Information	Concept	Interpretation and Inference
Purpose	1					
Question at Issue	-0.188	1				
Assumption	-0.235	0.561	1			
Information	0.199	0.827	0.243	1		
Concept	-0.120	0.498	0.085	0.755	1	
Interpretation and Inference	-0.330	0.592	0.993	0.241	0.113	1

Questions that the students mostly struggled with were questions with a higher degree of complexity: the concept of a mixture (Figure 3) or physical-chemical change as presented previously in Figure 1. In the question about the concept of mixture, the students were presented with a video about a bowl of shaved ice dessert with cheese and different colored fruits as toppings (Figure 3). Only 39.3% of students can answer that the dessert is a heterogenic mixture, whereas 29% and 24.8% choose compound and homogenous mixture, respectively. This finding is in line with the previous studies (Ozalp and Kahveci, 2015; Kingir, Geban, and Gunel, 2013) that students found difficulty in understanding the concept of mixture.

For questions in Figure 1, students evaluated video about bananas with brown dots on its skin. In order to find out more clearly what happened to the banana, 16.2% of students chose the question "Did the fruit rot?", 23.1% chose "Is discolored (browning) fruit still edible?", and 33.3% choose "how long does the oxidation process take place in the fruit?". Only 27.40% chose question that could directly help them explore what caused the physical and chemical changes to occur in bananas, namely through the question "besides bananas, what fruit are prone to oxidation?". Schmidt and Volke (2003) conducted a study in Germany and found that students often confused with the term oxidation and oxidizing agent, reduction and reducing agent, or oxidation and reduction. Eilks, Moellering, and Valanides (2007) study further corroborated students' difficulty in understanding the dynamics of chemical change of matter. Students' insufficient understanding of chemical and physical changes of the matter was also suggested by Ahtee and Varjola (1998), in which this insufficient understanding was found in 80% of students in their study. Those studies indicate that physical-chemical change is a subconcept that many students struggle to comprehend, thus critically think the process in daily life problems proved to be far harder.

Based on each critical thinking skill score for each critical thinking element, students have the best skills to understand the desired goal or outcome (purpose) while having the poorest skills in identifying an issue or problem that needs to be addressed (question at issue). Skills in making pre-suppositions and viewpoints (assumptions), understanding theories, definitions, rules, and laws that govern our thoughts and actions (concept), the understanding substance of thought which will be

the material to develop ideas and synthesize new thought (information), as well as making sense of data and reasoning from it toward a goal (interpretation and inference) are in low to moderate category (Figure 3). To understand further how each critical thinking skills element correlates with each other, we conducted a correlation analysis (Table 1).

Correlation analysis result suggested that students' skills in addressing the question at issue correlate with their skills in using clear, accurate, and relevant information to the question (correlation coefficient or $r = 0.827$), while identifying correct assumptions correlates with students' skills in making interpretations and drawing inferences ($r = 0.993$). Skills in using clear, accurate, and relevant information also correlate with skills in identifying the key concepts and stating them clearly ($r = 0.755$). In summary, skills in using clear, accurate, and relevant information predictively correlate with skills to addressing issues and identifying the corresponding key concepts. This result corroborates previous findings on the importance of clear and accurate information (Zhu et al., 2011). Holmes et al. (2015) also emphasize the importance of utilizing information or data. They pointed out that making a decision based on available data is a fundamental goal of education but rarely achieved. Although on a positive note, their study found that this quantitative critical thinking development can be achieved through repeated practice with sufficient feedback.

Correct assumption is found to be highly correlated with students' skills in making interpretations and drawing inferences which are in line with Fortus (2009) study. In his study, Fortus (2009) suggested that making assumptions for converting real-world problem into a well-defined one was the most challenging step in solving a real-world problem, and if ones were able to make the needed assumptions, they would be able to solve a real-world problem, i.e., arriving in the correct interpretation and inference. Yip (2001) emphasize that students' ability in making assumption cannot be expected to be acquired conventionally but rather by making further opportunities to learn in assuming various situations. Taking this present study result into account, moderately low skills in making an assumption as well as making interpretation and inference suggested that building these skills in the students is still very much needed.

Barak et al. (2007) study found that purposely teaching to promote higher-order thinking skills resulted in students' critical thinking enhancement. In their study to senior high school students, purposely teaching to promote higher-order thinking resulted in enhancement of analysis, evaluation, and inference skills. Barnett and Francis (2012) result also resonate with Barak et al. (2007) that teaching higher-order thinking improves students' critical thinking. Although Barnett and Francis (2012) sample was undergraduate students, their findings showed that student' assumptions and deductions skills were improved. The studies showed that improving critical thinking can only be achieved by making the goals explicit in the course, a notion supported by Abrami et al. (2008) meta-analysis results. Mixed instructional approaches that combine both content and critical thinking instruction significantly outperformed all other types of instruction (Abrami et al., 2008). Barak et al. (2007) further suggested three teaching strategies identified as promoting higher-order thinking skills: dealing with real-world cases, open-ended class discussions, and fostering inquiry-oriented experiments. The benefit of learning by dealing with real-world cases in a realistic scenario was also empirically verified in Lee et al. (2016) study. Therefore, the success of critical thinking attainment efforts lies in how the teachers deliver science concepts and how critical thinking improvement strategies are embedded within the instruction.

The present study suggested that students' critical thinking of heat and matter concepts could be the focus for further study in physics education. Although the sample was comparatively smaller than other studies, data from more than 100 students can prove the result's validity and reliability.

CONCLUSION

Critical thinking skills score, showed that students' ability in thinking critically for daily problems connected to heat and matter concepts was moderate. From each critical thinking element, students have the best skills in understanding the desired goal or outcome (purpose) while having the poorest skills in identifies an issue or problem that needs to be addressed (question at issue). Skills in using clear, accurate and relevant information may leads to the skill to addressing issue and identify the corresponding key concepts while making assumptions highly cor-

related with skills in making interpretation and inference.

A wide breadth of studies showed that the success of critical thinking attainment efforts lies in how the teachers deliver science concepts and how critical thinking improvement strategies are embedded within the instruction. Therefore, improvement in students' critical thinking of heat and matter rely on how the teachers composed instruction embedded with critical thinking improvement strategies and heat and matter concept. Further empirical study can examine how instruction embedded with critical thinking improvement strategies resulted in students' critical thinking of heat and matter.

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