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HIGH SCHOOL STUDENTS' MODEL OF UNDERSTANDING ABOUT STATE OF THE MATTER CHANGES

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ABSTRACT

Daily life events concerning the state of the matter were found prone to alternative conceptions, it is essential to identify learning difficulties and remediate learners' understanding mistakes. By categorizing students' model of understanding, the part of understanding that should be remediated can be elucidated. This study focused on uncovering high school students' model of understanding regarding the state of matter changes with forty 10^{th} grade students as sample. Results suggested that only a small portion of the sample have an optimum model of understanding in which most students only have a theoretical or even inappropriate model of understanding.

ABSTRAK

Peristiwa kehidupan sehari-hari mengenai wujud zat rentan terhadap konsepsi alternatif sehingga penting untuk mengidentifikasi kesulitan belajar dan memperbaiki kesalahan pemahaman peserta didik. Dengan mengategorikan model pemahaman siswa, bagian pemahaman mana yang harus diperbaiki dapat terjelaskan. Penelitian ini difokuskan untuk mengungkap model pemahaman siswa SMA tentang perubahan wujud zat dengan sampel empat puluh siswa kelas 10. Hasil penelitian menunjukkan bahwa hanya sebagian kecil sampel yang memiliki model pemahaman optimal yang mana sebagian besar siswa hanya memiliki model pemahaman teoritis atau bahkan tidak sesuai.

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INTRODUCTION

The state of matter is a concept that has been fascinating the scientists. Nils Wallerius (1706-1764) for example spent an extended portion of his life studying and documenting characteristics and factors of evaporation. It also took almost forty years from when Carl Graeber experimented in finding chloroacetophenone melting point until Frederick Lindemann published his Lindemann's criterion for predicting the melting point of substances. In 1995, approximately seven decades after Albert Einstein and Indian mathematician Satyendra Nath Bose theoretically predicted the possibility of producing the Bose-Einstein Condensate (BEC, dubbed as the fifth state of matter) in 1925, Eric A. Cornell, Wolfgang Ketterle, and Carl E. Wieman successfully produced BEC (this achievement granted them their Nobel prize for physics in 2001). Those events unveil the complex nature the state of matter concept and, thus, the challenge of understanding it. Understanding BEC is undoubtedly difficult, but simpler events in daily life concerning the state of the matter were also found prone to alternative conceptions (misconceptions).

Studies found that water droplets formation on a room temperature-water bottle (Gopal, Kleinsmidt, Case, and Musonge, 2004), the presence of bubbles in boiling water (Alwan, 2011; Aydeniz and Kotowski, 2012; Gultepe, 2016), the mechanism of rain (Thompson and Logue, 2006; Michail, Stamou, and Stamou, 2007) or the difference between melting and dissolving (Durmuş and Bayraktar, 2010; Smith and Nakhleh, 2011) were commonly misunderstood. Other studies also proved that misconceptions about the state of matter were widespread across the educational level, from junior high school students (Tsitsipis, Stamovlasis, and Papageorgiou, 2012; Slapničar, Tompa, Glažar, and Devetak, 2018), senior high school students (Adadan, Irving, and Trundle, 2009; Treagust et al., 2010; Kirbulut and Geban, 2014) to preservice teachers (Tatar, 2011). Liu and Lesniak (2005) study evaluated elementary to senior high school students' understanding of matter, and they found that students faced difficulties in understanding the state of matter changes, such as physical and chemical properties changes. They further highlighted the complex nature of the concept as reflected by understanding progression patterns and the educational level: junior high school students may understand physical properties and changes, but they may not understand chemical properties and changes. In contrast, high school students may be able to understand the kinetic and atomic models of chemical and physical changes, but it remains doubtful whether they can understand theories about bonding or not.

Saglam-Arslan and Devecioglu (2010) argue that detecting and replacing alternative conceptions is necessary, but effective learning is also facilitated by identifying learning difficulties and remedying learners' mistakes. In achieving the goals, they modified an understanding model hierarchy in which understanding was categorized into six understanding models: inappropriate model, memorizing model, practical model, theoretical model, uncreative model, and optimum model. By categorizing students' model of understanding in these six models of understanding, the level of understanding and which part of understanding should be remediated can be elucidated. Saglam-Arslan and Devecioglu (2010) category were used for revealing students' model of understanding of Newton's law of motion, and considering its effectiveness in probing students' level and model of understanding, this present study uses the category to probe students' understanding regarding such complex model as the state of the matter changes. Studies (Liu and Lesniak, 2005; Adadan et al., 2009; Treagust et al., 2010; Aydeniz and Kotowski, 2012; Kirbulut and Geban, 2014) also found that senior high schools students' understanding of the state of matter is a vital area of interest, and therefore, this study focused on uncovering high school students' model of understanding about the state of matter changes.

METHOD

The sample was 10^{th} grade students in one of the high schools in West Bandung, which consisted of 40 students (22 female and 18 male). The instrument used to collect data in this study consisted of conceptual understanding tests about *Changes in the States of Matter* or abbreviated as CSMCUTest. The test consisted of four items related to melting, evaporation, condensation, and deposition (Table 1), with scoring and categorization criteria presented in Table 2.

RESULTS AND DISCUSSION

Students' test results suggested that out of forty students, only four students (10%) had an optimum model regarding evaporation, and six students (15%) reached an optimum model of understanding for condensation. It is also unfortunate that no students have an optimum model of understanding regarding melting and deposition. Most students have a theoretical model regarding melting, evaporation, and condensation, while almost half the students (18 or 45%) only have an inappropriate model regarding deposition. These results proved earlier findings that students still have difficulties in understanding melting, evaporation, condensation, and deposition (Gopal et al., 2004; Thompson and Logue, 2006; Adadan et al., 2009; Durmuş and Bayraktar, 2010; Treagust et al., 2010; Alwan, 2011; Smith and Nakhleh, 2011; Tatar, 2011; Aydeniz and Kotowski, 2012; Tsitsipis et al., 2012; Kirbulut and Geban, 2014; Gultepe, 2016; Slapničar et al., 2018).

Students were asked to explain concepts related to ice melting and explain another phenomenon of state of matter changes. The highest model of understanding melting achieved by 22.5% or 9 students was the uncreative model in which student correctly defines, utilizes, and applies any piece of theoretical knowledge but fails in exemplifying it. Almost half of the students (18 or 45%) were even unable to apply their knowledge about melting. Inability to apply theoretical knowledge was also found in the highest percentage for evaporation and condensation questions. Fifteen or 37.5% of students and twelve or 30% of students could not apply their theoretical knowledge about evaporation and condensation. Regrettably, students' model of understanding of deposition only reaches the lowest model of understanding (inappropriate model) in which student fails in defining, utilizing, applying, and exemplifying any piece of theoretical knowledge.

Cukurova, Bennett, and Abrahams (2017) stated that the model of understanding consisted of two hierarchical processes, knowledge acquisition (scientific facts) and the ability to apply to a novel context in which one process leads to the other.

Table 1. Changes in the States of Matter Conceptual Understanding (CMSCU) Test

Item	Concept	Description of item test
1	Melting	A. When the ice is placed somewhere that has room temperature (300K), then the ice will gradually change into water. Explain why the ice can change into water! (explanation is expected to reach the microscopic level) B. What physics concepts are used to explain the phenomenon of changes in ice states from solid to liquid? C. Give another example which is similar to the phenomenon of changing the states of ice into water! D. Please define the concept of Physics that is used to explain the phenomenon of changing states from ice (solid) to water (liquid)
2	Evaporation	A. When we dry wet clothes after washing, a few moments later the clothes will dry out. Explain how wet clothes can dry out through the drying process! (explanation is expected to reach the microscopic level) B. What physics concepts are used to explain the phenomenon of dry wet clothes when drying? C. Give another example that is similar to the phenomenon of dry wet clothes when drying! D. Please define the Physics concept used to explain the phenomenon of dry wet clothes when drying!
3	Condensation	A. When we put ice into drinking water in a glass, then a few moments later water drops will stick to the outer glass wall. Explain how the water drops can form and stick to the outer glass wall! (explanation is expected to reach the microscopic level) B. What physics concepts are used to explain the phenomenon of the formation of water drops that stick to the glass wall? C. Give another example that is similar to the phenomenon of the appearance of drops of water sticking to the wall of the glass! D. Please define the Physics concept that is used to explain the phenomenon of the appearance of water drops attached to the glass wall!
4	Deposition	A. When we cook water in a pan by using wood fuel, then on the outside wall of the pan it will stick to charcoal. Explain how charcoal can form and stick to the outer wall of the pan! (explanation is expected to reach the microscopic level) B. What physics concept is used to explain the phenomenon of the formation of charcoal that stick to the wall of the pan? C. Give another example that is similar to the phenomenon of the appearance of charcoal that sticks to the wall of the pan! D. Please define the Physics concept used to explain the phenomenon of the appearance of charcoal that stick to the wall of the pan!

Table 2. Guidelines For Determining High School Students' Model of Understanding Based CSMCUTest

Model of Understanding	Scoring
Optimum Model (OM) *Student properly defines, utilizes, applies and exemplifies any piece of theoretical knowledge.*	Scoring applied to all questions: a. Correct: Score = 2 b. Close to correct: Score = $1 < S < 2$ c. Close to incorrect: Score = $0 < S < 1$ d. Incorrect: Score = 0 Scoring for Optimum Model: - Question A: $1 < S \leq 2$ - Question B: $1 < S \leq 2$ - Question C: $1 < S \leq 2$ - Question D: $1 < S \leq 2$
Uncreative Model (UM) *Student properly defines, utilizes and applies any piece of theoretical knowledge but fails in exemplifying it.*	Scoring for Uncreative Model: - Question A: $1 < S \leq 2$ - Question B: $1 < S \leq 2$ - Question C: $0 \leq S < 1$ - Question D: $1 < S \leq 2$
Theoretical Model (TM) *Student properly determines and defines any piece of theoretical knowledge but fails in applying and exemplifying it.*	Scoring for Theoritical Model: - Question A: $0 \leq S < 1$ - Question B: $1 < S \leq 2$ - Question C: $0 \leq S < 1$ - Question D: $1 < S \leq 2$
Practical Model (PM) *Student properly applies and exemplifies any piece of theoretical knowledge but fails in determining and defining it.*	Scoring for Practical Model: - Question A: $1 < S \leq 2$ - Question B: $0 \leq S < 1$ - Question C: $1 < S \leq 2$ - Question D: $0 \leq S < 1$
Memorizing Model (MM) *Student properly defines any piece of theoretical knowledge as the books do but fails in utilizing, applying and exemplifying.*	Scoring for Memorizing Model: - Question A: $0 \leq S < 1$ - Question B: $0 \leq S < 1$ - Question C: $0 \leq S < 1$ - Question D: $1 < S \leq 2$
Inappropriate Model (IM) *Student fails defining, utilizing, applying and exemplifying any piece of theoretical knowledge.*	Scoring for Inappropriate Model: - Question A: $0 \leq S < 1$ - Question B: $0 \leq S < 1$ - Question C: $0 \leq S < 1$ - Question D: $0 \leq S < 1$

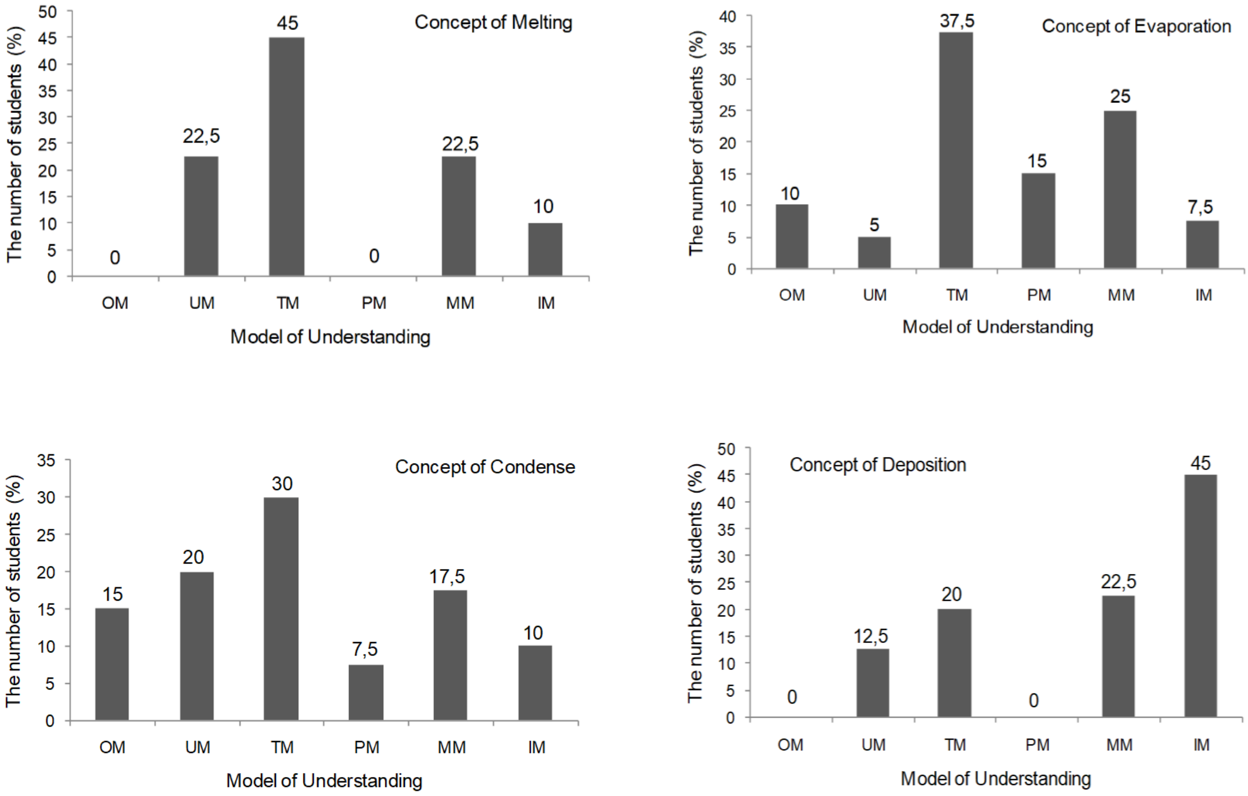

Figure 1. Students' Model of Understanding in Each State of Matter Changes Concept

Furthermore, the high occurrence of memorizing model in this present study suggested that students are still dependent on rote memorization in learning which Henderleiter, Smart, Anderson, and Elian (2001) suggested that the inclination to be highly dependent on rote memorization makes students cannot correctly apply theoretical knowledge to different science contexts or problems. Cukurova et al. (2017) study found that students failed to connect critical ideas of the investigated topic and focused instead on extraneous context. They further argue that insufficient support when learning makes knowledge acquisition and the ability to apply the knowledge did not change significantly after learning.

Classroom activity observation showed that teachers teach state of matter changes materials by giving the students terms and definitions for the state of matter changes. Teacher also gave identifying and distinguishing qualities needed to understand the definition to ensure that students find examples related or unrelated to the concepts. This practice indicates that the teacher still uses the traditional teaching approach when teaching the state of the matter concept in which the approach limitedly facilitates the attainment of an optimum model of understanding. Hwang and Roth (2011) argue that traditional physics lecture is meaningful if there are synergistic and irreducible transactions in many different communicative modes in which technology such as the use of media increases the communicative productions in knowledge transfer. Wibowo et al. (2017), as well as Srisawasdi and Siriporn (2014) studies, corroborated Hwang and Roth (2011) argumentation that using technology aided the attainment of meaningful understanding. Wibowo et al. (2017) further found that virtual simulation effectively remediates students' misconceptions about the state of matter changes with more than 75% students' misconceptions of the state of matter changes is remediated after learning.

CONCLUSION

Only a small portion of students had an optimum understanding model. The results showed that the high school student' have weaknesses in understanding the state of matter changes. This may stem from the lack of students to relate scientific knowledge with natural life phenomena and experiences. The traditional teaching approaches cannot be entirely relied on to promote students in achieving an optimum model of understanding because it does not involve students thinking, discussing, and discovering the physical meaning of the concept learned.

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