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EXPLORING MISCONCEPTIONS ABOUT *THE CHARACTERISTICS OF SOLID, LIQUID, AND GAS* AMONG JUNIOR HIGH SCHOOL STUDENTS IN KAMPOT PROVINCE, CAMBODIA

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Abstract

Research shows that students' misconceptions interfere with students' learning of scientific concepts. Meanwhile, the significant effects of students' misconceptions on their achievement has been a concern for teachers who strive to find ways of dealing with the misconceptions. This study was conducted to explore Cambodian students' misconceptions of states of matter (Solid, liquid, and gas), which main aimed to investigate what type of misconceptions which they held in the concept of characteristics of solid, liquid, and gas. Data was collected using a 15 multiple-choice two-tier test which was administered on 330 junior high school students in Kampot province, Cambodia. In this test, students' responses were categorized into three: correct answer, misconception, and incorrect answer. Data analysis through descriptive statistics showed the frequencies of each students' misconceptions. Students' responses to the items revealed that 20 misconceptions were held by less than 50% of the students whereas 4 misconceptions were held by more than 50% of the students who took the test. Interviews with some of the students revealed the nature of students' understanding of the concept of states of matter. Two main conclusions were derived to explain these results: 1) students tend to attribute macroscopic view to microscopic view and 2) students believe matter exist unless they see.

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INTRODUCTION

Most students aged 11-18 have misconceptions about the characteristics of solid, liquid, and gas (Barker, 1994). These misconceptions prevent students' learning because students find it difficult to understand scientific concepts (Nussbaum & Novak, 1976; Eaton, Anderson, & Smith, 1984). A study conducted by Boz (2006) in Turkey used a questionnaire on 300 pupils in grades 6, 8, and 11, to explore their understanding of arrangement and movement of particles of solid, liquid, and gas. Boz found that students thought particles of solids do not have any movement or vibration because there is no space between them. They thought that particles of solid substances are close to each other and strongly packed together to make the solid substance. This confirmed an earlier study conducted by Lee, Eichinger, Anderson, Berkeimer, and Blakeslef, 1993 who found that sixth grade students had difficulty understanding that particles are constantly in motion. Some students thought particles of a rock do not move because it was solid. Not only primary school students but also prospective primary school teachers held the same misconception. They wrote on a sheet of paper to describe the characteristics of solid, and they reported that particles of solid couldn't move since the particles were strongly connected to each other (Tatar, 2011). This misconception was also found by Dow, Auld, and Wilson (1978). Another interesting misconception was that particles of solid easily change in size, shape, or number after the solid undergoes a physical change (Gabel, Samuel, & Diana Hunn, 1987). For example, some students thought the size or number of particles of solid decrease after melting. Stojanovska, Petruševski, & Šoptrajanov, (2012) study also found that secondary and high school students in the Republic of Macedonia claimed that particles of substance either decrease or increase their size when a substance is heated. It appears that when viewing a particle aspect of solid, liquid, and gas, students often attribute what they see to what they do not see (particle view). Similarly, some studies showed students' understanding of space between particles. Aydin & Altuk, (2013) administered a questionnaire survey among science student teachers to measure their understanding of the features of solid, liquid, and gas. Results showed that twenty three percent of them thought there were no spaces between the particles of solid substances. This result was similar to Novick & Nussbaum, (1978) research conducted on Israeli students, which also found that 25% of the younger group had a misconception about spacing between particles. They claimed that there was something filling in the space between particles, either dust or other particles. Their perceptions meant that there was something between particles, or there was no space between particles, or the particles are closely packed together. Ben-Zvi, Eylon, and Silberstein (1987) investigated the young pupil's perceptions and found that the students attributed macroscopic view of materials to particles view. Pupils' responses were that the concept of melting, or dissolving of material or substance, occurred in particle view as well. A study conducted in Taiwan by Chiu, Chiu, and Ho, (2002) focused on the characteristics of solid, liquid, and gas particles. The study found that students believed that solid particles sink to the bottom of the container and float when changing from solid state to liquid state. Their beliefs suggested that particles of solid are non-interaction substances. The adoption of particle concept is not always in accordance with scientific view. Moreover, students described a lot about gas particle characteristics which were contrary to the meaning from scientific point of view. Another detailed study was conducted in Turkey with a sample of 195 high school students, using a three-tier diagnostic test, which contained three parts in each item. The first part of the test allowed students to choose the answer of the phenomena; the second part let students provide the reasons to support a choice made in the first part; and the last part gave the students a chance to choose yes or no answer for claiming confidence of their choice in the first and second parts. The study results showed a frequency of students' misconceptions and they thought that when gas is compressed, its particles would change shape, while when gas is heated, the particles would expand. They thought either when compressing, the force affects changing of the shape of particles or the heat would be able to expand the shape of particles too (Kirbulut & Geban, 2014). The students' wrong beliefs do not only relate to the particles aspect, but also the physical aspect. Based on their experiences in daily life, they may misunderstand some points of solid, liquid, and gas. In their study, Jones and Lynch (1989) reported that students viewed solid in two meanings: one referred to hard substance and the other referred to the type of matter. In Tasmania, students from grade 1 to 6 viewed the word solid as an adjective describing the hard substance in an object. They did not explain it as a noun, which means classification of a substance or type of matter. Moreover, 200 of Israeli students from grades 1 to 7 were involved in the study of classification of solid and liquid, and they failed to consider non-rigid substances as solid (Stavy & Stachel, 1985). They believed that solid must be a hard substance. So, their judgement of states of materials was based on the appearance, and not according to the type of the materials. When students face difficulties with classifying solid and liquid, there is a chance of misconceptions related to liquid characteristics. While students considered hard object as solid, studies by Stavy and Stachel (1985) and Tatar (2011) revealed students' conceptions about what a liquid is. The students thought that something which can pour must be considered as liquid. They judged sand as liquid while they mentioned that honey is not liquid because it is sticky and cannot pour. Moreover, the study conducted by Shepherd & Renner (1982) found that students viewed liquid as pourable substances. Some students distinguished liquid as something wet and soft, something that can flow and be poured, and something that can be drunk (Demirbaş & Ertuğrul, 2014).

As we could see, the students had various type of misconceptions which provided them difficulty to understand the right concepts. They had different ideas may stuck in their mind for long time. As researcher have to think what kind of idea that they already had in their mind? The present research was motivated by the growing concerns about the state of science teaching and learning in Cambodia, and the need to provide evidence on which interested stakeholders could base their interventions as they plan to improve science education in the country. One of the concerns is that, according to PADECO CO (2009) most science classes are done in talk and memorize style without paying attention to students' misconceptions. Moreover, the students' achievement scores of understanding the concept of matter is lower than Asian and Japanese students. As such, the report in Education Strategic Plan (ESP 2014-2018) of Ministry of Education, Youth and Sport (MoEYS) seeks to improve students' understanding of scientific concepts (MoEYS, 2014). Among others, the government is working on improving teachers' Pedagogical Content Knowledge (PCK). PCK describes the knowledge that teachers use to transform subject matter for students learning, including the conceptions, misconceptions and learning difficulties of their learners (Shulman, 1987) . Premised on these considerations, this research aimed to explore the students' misconceptions about the particle and physical characteristics of solid, liquid, and gas. Responding to the objective of this study, one research queston was conducted that what are the students' misconceptions of the state of matter in terms of the characteristics of solid, liquid, and gas?

METHOD

Instrument

The tools used in this study were mainly using two-tiers diagnostic test and interview. Most researchers believe diagnostic test is appropriate for measuring students' understanding especially their misconceptions (Ray Peterson, Treagust, & Garnett, 1986; Tsui & Treagust, 2010), and interview provide an opportunity for seeking out the details of their understanding (BouJaoude, 1991; Abdullah & Scaife, 1997; Nakhleh & Samarapungavan, 1999). The study adopted a States of Matter Diagnostic Test (SMDT) from Treagust et al., (2011) and Kirbulut and Geban (2014). Test items were also constructed with content drawn from the Cambodian 7th-grade chemistry textbook. The test consisting of 15 multiple choice items carefully measured the students' understanding of the physical and particle characteristics of solid, liquid, and gas. As shown in example below was a test item number 12 which intended to measure students' understanding of characteristics of gas on the point of mass of gas. This instrument was also reviewed by chemistry teachers at the four schools for assuring content validity and was found to be appropriate for this study. In terms of structure, each diagnostic test item had two main parts: the first part was about targeted contents on the characteristics of solid, liquid, and gas regarding particle and physical characteristics; and the second part focused on students' reasons for their choices in the first part. Moreover, in the second part of the test, the researcher provided a blank space for students to write their own reasons in case they had other reasons different from what they provided in the second part of the test items.

Test item number 12

You shake a bottle of soda water, and then you open the cap. Then you hear the sound of gas bubbles come out from the bottle.

12.1. The mass of a bottle of soda water will be:
A) □ Constant
B) □ Decrease
12.2. Reasons:
A) □ Gas has no mass, so it does not affect mass of soda water.
B) □ Gas has mass.
C) □ Gas flies and disappears.
D) ……………………………………

Sample

The diagnostic test was administrated to a total of 330 junior high school students from four different schools in Kampot province, Cambodia. Those four schools were purposively choosing among rural and urban schools in attempt to generalize the students' understanding in that province. The classes which involved in the test were randomly selected in each school due to school principal categorize class disregarding the students' ability. Thus, all classes in each grade were assumed to be equal in terms of their ability. A total of 60 students were selected purposively from the sample to involved in interview to gain more in-depth explanation about their understanding.

Data collection

Base on the study design, there were two steps of collecting data which follow quantitative and qualitative method. First, applying diagnostic test was easily administrated to larger sample and it can allows to calculate the percentage of correct answer, incorrect answer, and misconception. The tests were distributed to 330 sample in a normal class condition. The classes and was completed within 50 minutes. The researcher was in the class in order to ensure the testing procedure without any cheating. After finishing the test, researcher captured the result with the most frequent misconceptions and selected students for interview about that misconceptions. Semi-structured interview was conducted with 60 students who finish the test. The interview protocol was only about asking why they thought so regarding their answer in the test.

Data analysis

Data was analyzed by using descriptive statistics showing the percentage of students' responses from the diagnostic test. Measures of frequency and percentages were used to describe students' responses which were categorized into three responses: incorrect answers, misconception answers, and correct answers. These categories meant the following:

Incorrect answer	Misconceptions	Correct answer
This category includes a completely correct answer in both parts of the test items	Researcher followed two types of rubric based on the nature of the test. The rubric based on Treagust (1986) and Tsui and Treagust (2010). The first rubric followed Treagust (1986) who demonstrated that students have misconceptions if the students chose the **correct answer in the first part** and **incorrect answer in the second part of the test item.** When they choose like that, it means that they understand the concept on the specific content in the first part, but they couldn't explain the right reason in a scientific way in second part. Their incorrect choice in the second part of the test shows their misconception of that concept. The second rubric followed Tsui and Treagust (2010) who maintained that when students chose the **wrong choice in the first part** and **a related wrong reason in the second part** of a test item, it was considered as a **specific misconception response**. This type of choices showed their specific relevant meaning based on their opinions which reflect their misconception, and those choices make sense for them. Both wrong related choices in the first and second parts show specific misconceptions of the concept.	this choice was neither correct nor a misconception

The students' responses were copied into an excel file and coded for easy understanding of each variable. The excel file provided an easy way to record data in many columns (sex, grade, group, test items) and rows (about 330 rows, number of students). The data was then transferred into a Statistical Package for the Social Science version 21 (SPSS) for descriptive analysis and so on. SPSS was specifically used to measure frequencies and percentages of students' responses in each of the above indicated categories. Moreover, SPSS could investigate the relationship between variables.

For the interview data, the researcher transcribed the students' responses. Then, recurring issues were identified for interpretation to understand reasons for the students' misconceptions.

RESULTS

Based on the 15 test items of State of Matter Diagnostic Test, we found 24 misconceptions of characteristics of solid, liquid, and gas. Additionally, there were four misconceptions which were common and held by over half of the sample. Those misconceptions showed what students think about particle and physical characteristics of solid, liquid, and gas as shown in table 1. One among four common misconceptions was about gas characteristic. As shown in test item number 2, it tested the students' understanding of the movement of gas particles. The students' responses showed the unique misconception in this study. There were 58.8% of the students who thought "gas particles move everywhere because of wind". From the test, students responded that they could smell gas from the other side because wind brought those gases. They thought wind was the force behind the movement of gas particles. Another common misconception was about characteristic of liquid. Regarding the understanding of liquid particles, most students in this study had a misconception of space between liquid particles. The background of this question was that students aged from 11 years-old start thinking about abstract concepts, so they sometimes get confused by what they see and what they don't see. The phenomenon in the test was a mixture of alcohol 50ml and water 50ml, to which the students responded that the volume of the mixture would be 100ml. Furthermore, 50.3% of the students (shown in Table 18 below) thought that there were no spaces between the particles of liquid. They thought the volume of the mixture decreased to less than 100ml because some alcohol particles had 'escaped' out of the bottle. Students didn't think about some connection between alcohol and water particles which lead to the decreased volume. Apart from gas and liquid misconception, most students in this study tend to think differently from science concept about solid particle when melting. There were about 65.8% of the students who confirmed that ice decreased in mass after melting. They thought "the size and number of ice particles decrease when ice is melting". The last common misconception in the finding of this study was gas has no mass. To test students' understanding of some physical characteristics of gases, one test item asked them to explain the changes in mass of bottle of soda water before and after opening the cap of the bottle. Most students, about 51.5% thought the opening the bottle of soda water would release gas from the bottle. Therefore, mass of soda water would be constant because the released gas bubble had no mass for effecting the change of mass of soda water.

Table 1. Summary of Students' Misconceptions in this Study

	Description of Misconceptions	Percentage of students %	Common misconceptions
Particle characteristics of solid, liquid, and gas	When temperature decreases, gas particles shrink.	46.4	
	When temperature decreases, number of gas particle would decrease.	34.8	
	Gas particles move everywhere, because the wind blows them and they are light.	58.8	√
	When compressing, number of gas particle decrease.	8.5	
	When gas is compressed, particles shrink.	21.5	
	When gas is compressed, particles stick together.	4.8	
	When gas is compressed, particles are all pushed to the end of the syringe.	37.9	
	Particles escaped to make changing in volume of liquid.	40.9	
	Liquid particles move freely to make changing in volume	26.1	
	There is no space between particles	50.3	√
	Heavier ink particle sinks to the bottom of the tube	23.9	
	Particle of liquid cannot move	14.5	
	Size and number of particles decrease when a solid is melted.	65.8	√
	Size of solid particles decrease when solid is pressed	20.6	

Description of Misconceptions		Percentage of students %	Common misconceptions
Physical characteristics of solid, liquid, and gas	Solid must be hard	25.8	
	Substances which can flow are liquid	19.7	
	Substances which are powdery are considered as liquids	38.8	
	Gas has no mass.	51.5	√
	Hot air and cold air are weightless	23.6	
	Hot air is heavier than cold air	17.9	
	Liquid weight more than gas	40.0	
	Water vapor is weightless	14.8	
	All liquids must be watery	14.5	
	All substances can be poured are liquid.	7.6	

DISCUSSIONS

This study found twenty-four misconceptions of the concept of characteristics of solid, liquid, and gas held by junior high school students. The misconceptions showed the common idea which students had in their mind. Basically, those misconceptions reveal two types of thinking: firstly, students tend to attribute macroscopic view to microscopic view, and secondly, they believe existence of matter unless they see it.

The idea of "attribution of macroscopic view to microscopic view"

This idea was reflected in the misconception that "there is no space between liquid particles" which was held by 50.3% of the sample. Students explained that they didn't see any space in liquid state, so it would be the same with particle state of that liquid. For instance, in an experiment when they mixed 30ml of water with 30ml of alcohol, they supposed that the total volume of the mixture would be 60ml. They believed either 30ml of water or 30ml of water would fill the 30ml space based on what they saw. The particles of liquid remained firmly connected, and they strongly believed there was no space between particles.

The idea of "seeing is believing":

There were 58.8% of the sampled students who thought "gas particles move because of blowing of wind". Students had difficulties understanding that particles or molecules of matter are constantly in motion. According to their thinking, the movement of gas particles is only possible with external forces such as wind. And, the existence of wind is showed by the movement of a tree leaf or the feeling of cold or hot on their skin. This finding is similar to Séré's (1986) study of the existence of air. Séré found that pupils aged 11 thought gas exists only when it moves, so they could see the movement. It means that they needed to see something or feel it before they confirm its existence. Moreover, the misconception "gas has no mass," which was held by 51.5% of the sample also implied the idea of seeing is believing. This misconception came from students' ideas of existence of matter. Students viewed gas as something invisible and difficult to catch, so they thought this thing didn't exist in the world. And, they believed non-matter doesn't have mass. So, when gas was considered as non-matter, they concluded that it has no mass. The idea of this concept was also confirmed by some studies such as Stavy (1990). The children aged 9-15 who participated in the Stavy's study explained that "there was existence of matter since it can be seen". Overall, students believed matter exists only when there is evidence of its existence. According to students' explanations, the concept of "seeing is believing" make sense for them to understand things in the world.

CONCLUSION

This study has some limitations, especially in the scope of domain studied and generalizability of the results. Exploring misconceptions of "states of matter" in this study was only limited to the domain of misconceptions related to particle and physical characteristics of solid, liquid, and gas. We therefore suggest that a study focused on students' misconceptions of other characteristics would produce comparable results. Future studies could also attend to the students' misconceptions in other scientific concepts.

Despite these limitations, we note that this study provides important insights for science teaching. Two main conclusions were derived to explain students' misconceptions: 1) students tend to attribute macroscopic view to microscopic view and 2) students believe matter exist unless they see. While it is uncommon to view such students' misconceptions in negative terms, we propose that teachers can also use the misconceptions as stepping stone for meaningful learning, especially as advocated by constructivists such as Dewey (2007). Notably, if teachers know what students already have in their mind before class, they can prepare appropriate teaching activities to support the students' learning.

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