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EXPLORING STUDENTS' CONCEPTIONS ON THE NATURE OF MATTER USING PARTICULATE ILLUSTRATIONS

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Chemistry is a science whose primary purpose is to describe and explain matter and the changes that it undergoes. The nature of matter is identified in science education as one of the fundamental concepts that students should understand. Thus, it is not surprising that all chemistry topics are concerned in one way or another with the study of atoms, ions, and molecules. Further, it provides a foundation for understanding other chemistry concepts, such as: changes in state, chemical reactions, and behavior of gases.

However, empirical studies in science education indicate that students have difficulty understanding the structure of matter and hold several alternative conceptions of atoms and molecules. For example, some students believe that a molecule changes its size and shape at different temperatures. Additional studies show that students have difficulty relating macroscopic properties to the movement and arrangement of particles, even after engaging in substantial chemistry instruction (Ben-Zvi, et al. 1986).

Within the growing interests' in students' conceptions on the particulate nature of matter, a lot of empirical studies have been carried out. Some researches lead to new instructional approaches related to the results found by the researchers. Very few studies look at the long term development of particle conceptions while others have used visual conceptual questions based on the particulate nature of matter to corroborate the discrepancy in science concepts (Sanger, 2000).

For the past decade or so, chemical education researchers have stressed the importance of asking students to think about chemistry concepts at the particulate level. The inclusion of particulate drawings in chemistry lessons suggests that when students receive such instruction, they are better able to answer conceptual questions that are particulate in nature. Many introductory college chemistry textbooks have evolved to include particulate drawings. Instructional methods using particulate drawing have been effective in helping students answer visual conceptual questions. This approach was also used to investigate on differential effect of using particulate drawing on the achievement of students (Bunce & Gabel, 2002).

Research studies suggest that for learning to take place meaningfully, students must be made aware of their prior conceptions and construct their own knowledge which could make sense to them. Novick and Nussbaum (1981) describe the basic learning problem as requiring learner to:

"… overcome immediate perceptions which lead him to a continuous, static view of the structure of matter. He must accommodate his previous naïve view of the physical world so as to include a new model adopted by scientists. Internalizing the model therefore requires overcoming basic cognitive difficulties of both a conceptual and a perpetual nature."

Before effective instruction can occur, it is important that the existing students' conceptions be identified and studied carefully. This is what this study tried to achieve by using particulate illustrations.

Statement of the Problem

The main purpose of this study is to explore students' understanding of the nature of matter using particulate illustration.

Specifically, this study answered the following questions:

1. What are the students' conceptions of the nature of matter?
2. What are the levels of students' understanding of the nature of matter?
3. What are the students' perceptions about particulate illustration in chemistry?

Significance of the Study

The desperate need to find intelligible ways of teaching students the key concepts in chemistry is the main reason of this study.

The outcome of this study will provide science educators initial information on students' conceptions of the nature of matter. This knowledge can further impart valuable inputs to guide teachers in correcting these conceptions

This study will also help students to develop their views on the nature of matter and to develop their ability to learn about chemistry concepts at microscopic level.

Lastly, this can serve as a guide for the administrators in developing instructional materials that can be used in enhancing the learning of concepts in chemistry.

Scope and Limitations of the Study

The study was limited to the identification of students' conception of the nature of matter by using particulate illustrations. It also determined the level of students' understanding of the nature of matter and their perceptions about particulate illustrations in chemistry.

The study was conducted at the Technological University of the Philippines, Manila during the first semester of school year 2005-2006. The subjects of the study were first year students of College of Industrial Education enrolled in General Chemistry 1. The Visual Conceptual Questionnaire (VCQ) used in the study was adapted from Sanger (2000) and Bauer & Toher (1997). In describing the students' level of understanding, a conceptual trace analysis was performed, based on the work of Ferido (1995). The study was conducted during the first semester of school year 2005-2006.

Methodology

Research Design

This study utilized qualitative data in an attempt to explore students' conception of the nature of matter. The qualitative data were derived from the Visual Conceptual Questionnaire (VCQ), modified and based from the study of Sanger (2000) and Bauer & Toher (1997). Additional qualitative data were obtained from students' interview conducted after the results from the VCQ were derived.

Sampling Procedure

This study was conducted at the Technological University of the Philippines, Manila during the first semester of school year 2005-2006. The samples of this study were initially composed of one intact class, consisting of 40 first year students from the College of Industrial Education enrolled in General Chemistry 1. The visual conceptual questionnaires (VCQ) were administered to the whole class. From this group, a sample of nine (9) students to consist of three high, three average, and three low scorers in the visual conceptual questionnaire, were purposely chosen for further data analysis.

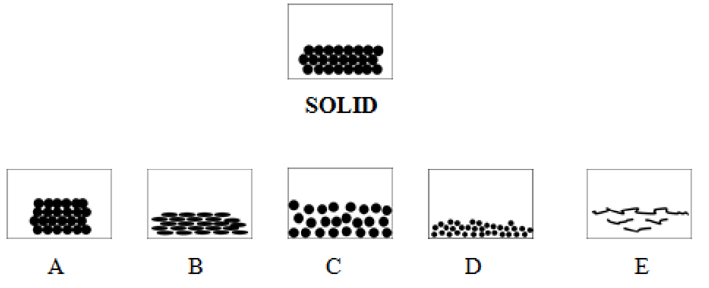
Research Instruments

The research instruments utilized in this study were the visual conceptual questionnaire (VCQ), scoring guide for the Visual Conceptual Questionnaire (VCQ), and an unstructured interview.

Visual Conceptual Questionnaire (VCQ)

The questionnaire used in this study was based from the works of Sanger (2000) and Bauer & Toher (1997). The questionnaire modified by the researcher, was designed to determine students' understanding of the nature of matter. The questionnaire is an open-ended forced choice type of test. It consists of 10 items multiple choice questions that address chemical concepts. The questions use particulate illustrations to exemplify chemistry concepts. A sample item (Item No. 1) in the visual conceptual questionnaire is shown in Figure 3

1. The container holds a pure solid. The molecules are represented by circles. What would the system look like after the solid has melted and become a liquid?



Please explain your answer.

Figure 3. Item No. 1 of the Visual Conceptual Questionnaire

The second part of the questionnaire meant to elicit students' conceptions of the nature of matter by manner of explaining their chosen answer on the first part of the VCQ. This part was evaluated and scored with the help of an expert.

Scoring Guide for the Visual Conceptual Questionnaire

This instrument was used as a key for scoring the Visual Conceptual Questionnaire (VCQ). The scoring guide is composed of answers in the multiple-choice and the open-ended portion of the questionnaire. Using this guide and its equivalent, each student can have a maximum score of forty (40) and a minimum score of zero (0).

Unstructured Interview

To determine how students were able to come up with their choices on the given test, an audio taped interview was given. The interview was conducted after the visual conceptual questionnaire (VCQ) was answered. This further explored and determined students' understanding of the nature of matter.

The last part of the interview focused on students' perception about the use of particulate illustrations.

Research Procedure

The respondents of the study were first year students from the College of Industrial Education enrolled in General Chemistry 1. Of the intact class consisting of 40 students, only nine (9) of them were purposely chosen and were considered in the final data analysis of the study.

The Visual Conceptual Questionnaire (VCQ) was administered after the completion of the Unit on Matter and Energy which was based on the syllabus used by the Chemistry Department of the Technological University of the Philippines.

Data Analysis Procedure

The students' understanding of the nature of matter was identified through the data gathered from the students' answer on the given visual conceptual questionnaire (VCQ). The conceptions identified were enumerated and discussed based on different chemical phenomena.

In determining students' level of understanding, only nine out of the 40 students of the intact class were chosen for the final data analysis. To provide a richer description of the level of students' understanding of the nature of matter, a conceptual trace analysis was performed. The conceptual trace analysis based on the work of Ferido (1995) was performed by considering the relationships between the students' multiple choice responses and their corresponding explanations for the questions on the given test.

From the responses gathered on the last part of the interview, students' perceptions about particulate illustrations were identified and enumerated.

Discussion of Results

From the results obtained in the study, the following misconceptions were identified:

- Spaces between particles are filled-up with various entities (such as dust, air, and different gases).
- Particles can change form (e.g. can change in shape or size, can shrink or expand).
- Matter has no permanent characteristic. When matter can no longer be seen, it ceases to exist, such as when sugar dissolves in water.
- Matter has a grasping core to which various random properties having independent existence are attached. Matter can "disappear" whereas its

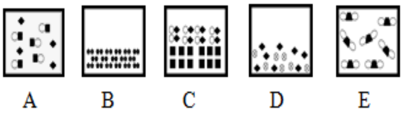
properties (such as sweetness) can continue to exist completely independent of it.

- Particles of matter break-up on heating and split up into tiny pieces.
- During evaporation, molecules of water separate to oxygen and hydrogen. Some of the particles however, could "disappear."
- Particles of solid "shrink" during melting.
- The results obtained from the study are as follows.

a) State of Matter

Table 1 shows the summary of students' understanding of the solid state of matter. It was determined that only one out of nine (1 of 9) students was able to identify the correct option. Further analysis of their explanations during the interview revealed various understanding as manifested in the open-ended portion of the questionnaire. Most of these respondents have the same reason that solid is made up of one kind of particle only and that there is no empty space between them. They explained their answer by stating that no place is completely empty. These students have difficulty accepting the notion of the existence of an empty space. For these students, any empty space must contain air, dust, gas and/or other particles.

Table 1
Summary of Students' Conception About the State of Matter (Item No. 3 in VCQ)

Item No.	Questions	Choices	Frequency of Response (n=9)
3	Here is a set of container that holds different substances. Imagine that you have a very powerful microscope that could see the molecules inside a container. How would the molecules of a solid substance look like? 	a.) A & E	1
		*b.) B & C	1
		c.) B only	5
		d.) C only	0
		e.) D only	2

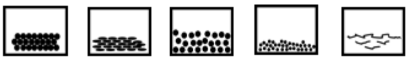
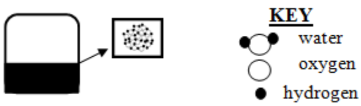
Note: *correct answer

b) Phase Change

Students' understanding of phase change is shown in Table 2. Results show that almost all (7 of 9) of the respondents believed that when solid melts, its particles change in size and shape. While one of the respondents held the wrong notion that particles of solid "shrink" when it melts, only one of the nine (1 of 9) respondents was able to answer correctly and explain melting in terms of molecular arrangement but not according to molecular motion. Students, clearly, did not realize that physical changes in matter could be explained not only through molecular arrangement but also through its motion.

Five of the nine (5 of 9) respondents held the notion that water molecules, during evaporation, separate to oxygen and hydrogen. In addition, there were 2 out of 9 students who considered that water molecules disappear during evaporation.

Table 2
Summary of Students' Conception About Phase Change (Item No. 1 & 5 in VCQ)

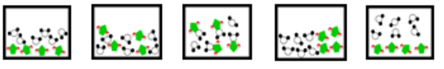
Item No.	Questions	Choices	Frequency of Response (n=9)
1	The container holds a pure solid. The molecules are represented by circles. What would the system look like after the solid has melted and become a liquid?	A	0
		B	1
	 SOLID	*C	1
		D	7
	A B C D E	E	0
5	The circle on the right shows a magnified view of a very small portion of water in a closed container.		
		A	1
		B	0
	What would the magnified view show after the water evaporate?	C	2
		D	4
	A B C D E	*E	2

Note: * correct answer

c) Physical Composition of Matter

Table 3 presents the summary of responses on students' understanding of composition of matter. Demonstrating the idea that the structure of sugar and water would remain unchanged and that the particles should be randomly mixed was common to 5 out of 9 respondents. There were 4 out of 9 students who assumed that sugar, when mixed with water disappears but its property such as sweetness is still there.

Table 3
Summary of Students' Conception About the Composition of Matter (Item No. 7 in VCQ)

Item No.	Questions	Choices	Frequency of Response (n=9)
7	Figure 1 represents 1.0 L of water. While Figure 2 represents the sugar molecules.	A	0
	 Figure1 Figure 2	*B	5
	Which response represents the view after the two substances are mixed together to form a solution?	C	4
	 A B C D E	D	0
		E	0

Note: * correct answer

Conclusions

The conclusions derived from the outcome of the study are the following.

Pertaining to students' conception of the state of matter, it was found out that most students were able to explain the molecular structure of solid and gas in terms of the degree of closeness and compactness of the particles as previously stated. It is worth noting though, that students have a better understanding of the gaseous state of matter as compared to the solid state. It is because of their belief that there should be no space between particles of solid.

On the other hand, almost all of the respondents have a sound understanding of phase change such as melting and evaporation in terms of molecular arrangement; however, they lack understanding of molecular motion.

As regards students' understanding of chemical composition of matter, the study revealed that the majority of students' have a better understanding of compounds than elements. The learners were able to visualize and explain the particulate illustration of compound formation but failed to clarify why the elemental components of compound vanish upon decomposition.

A considerable number of students indicate a good understanding of the nature of mixtures, both homogenous and heterogeneous, in terms of their molecular structure. On the contrary, there are few students who still use sensory reasoning when explaining abstract concepts.

Furthermore, considering students' conception of the Law of Conservation of Mass, it is evident that a large number of respondents perceived correctly that matter should always be conserved whether it undergoes physical or chemical change.

Relating to the levels of students' understanding of the nature of matter, clearly, it shows that the larger number of responses belongs to partial understanding (PU) category. However, it is followed by a considerable number of responses that fall under worst understanding (WU). This undoubtedly shows that students do not completely understand the nature of matter specially when asked to explain at the particulate level.

In connection with students' perception of particulate illustrations, as revealed in the interview, the use of particulate illustration in chemistry will help students understand and envision abstract concepts better and easier. It will also stimulate interest and enhance creativity of students, thus promoting sensible understanding.

Recommendations

Based on the outcomes of the study, the following are recommended:

- The Visual Conceptual Questionnaire used in the study may be adapted to determine students' conception of the nature of matter. Science teachers can determine their students' existing conception by using particulate illustrations before and after each instruction.
- Chemistry teachers, in particular can consider the use of particulate illustrations in teaching abstract chemistry concepts especially at a microscopic level.
- A similar study may be performed to explore on students' conception on other topics in Chemistry where the use of particulate illustrations can be possibly applicable.
- Further study may be conducted using more representative samples to further verify the validity of findings and results related to the use of particulate illustrations in chemistry teaching and learning.

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