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Mental Model in Learning Chemical Bonding: A Preliminary Study

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Abstract

Chemical bonding is one of the subjects that involves the use of models, varying from simple ones to sophisticated abstract models possessing considerable mathematical complexity. It is a topic that students commonly find to be problematic, developing a wide range of alternative conceptions. The fact is that students cannot see how the atoms or elementary particles are held together, and how they interact and bond together to form a compound. Students' misconceptions regarding these chemical bonding concepts begin when they live and operate in a macroscopic world and do not easily follow the shifts between macroscopic and microscopic levels. As a result, they tend to build a non-scientific mental model, which means that the idea is not aligned with scientific concepts. Therefore a preliminary study was conducted in order to investigate students' mental model in this topic.

Keywords: Chemical bond; mental model; macroscopic; microscopic; symbolic

1. Introduction

Models are one of crucial factors in understanding Chemistry [1, 2, 3]. Models and modeling ability play an important role in all science disciplines, but they are most important in Chemistry because this subject involves many abstract and complex concepts. It is impossible for chemical phenomena to be explained without the use of models [4]. Models are important to link the methods and science products rather than just being a communication tool [5]. Models are usually used when students learn the concepts of atoms, molecules and bonding.

When the teaching process involves the use of models, it is in accord with the development of mental models [4]. Justi and Gilbert [2] proposed that, by using models, students' understanding of Chemistry might be improved, as well as their ability to produce their own mental models. Nahum et al. [3] suggested that teachers should know how their students construct their mental models to make sure that the students do not develop the wrong mental models because mental models are vital in theory making and practice in Chemistry [6]. Nowadays, scientists emphasize the understanding of the three levels in chemical representation, which are the macroscopic, microscopic and symbolic levels. This is because these three levels are linked and understanding them reflects the development of mental models [7].

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2. Mental Model In Learning Chemistry

Chemistry concepts depend much on chemical representation and this contributes to the development of mental models. The three levels in chemical representation are linked and reflected in students' personal mental models. Students' mental models are built up through their experiences, interpretations and explanations when they are involved in learning Chemistry. Usually, the mental models developed are necessary for making predictions, testing new ideas and solving problems in learning Chemistry [8]. Johnstone [9] and Treagust et al. [10] argued that the three chemical representations (macroscopic, microscopic and symbolic) were interconnected with each other. The basis was the macroscopic level was followed by the microscopic and symbolic level to explain the process that occurs at a macroscopic level [9, 10]. Thus, Detevak [11] developed the Interdependence of Three Levels of Science Concepts, which is called the ITLS model (see Fig 1.) to explain the connection between the three levels and the integrated mental model as a factor in inducting knowledge into the long term-memory.

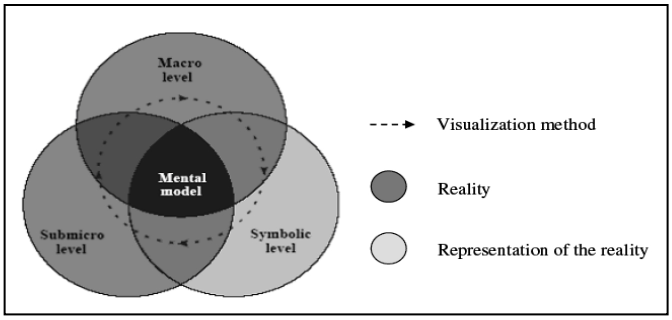

Fig. 1. The Interdependence of Three Levels of Science Concepts model [11]

3. Research Procedure and Data Analysis

A preliminary study was conducted to obtain an overview of the students' mental model in chemical bonding. The samples involved in this study were 28 Form 5 students from a school located in Johor. In this initial study, students were given a set of questions that consisted of two subjective questions, where students needed to describe the compound according to the three levels of chemical representation (macroscopic, microscopic and symbolic). The questions were designed according to the instrument used in the study by Jansoon, Coll and Samsook [12].

There are two types of questions that were asked to the students, where the first question required them to answer the three levels based on the experiment on Magnesium Oxide (MgO). The second question required students to answer based on the picture of salt (NaCl). All the students' answers were categorized into three themes and compiled into a Concept Profile Inventory (CPI) [13]. These categories were:

(i) Answer or statement given is aligned with the scientific concept
(ii) Answer or statement given is wrong or alternative
(iii) Does not answer the question or the given statement is difficult to understand

Table 1 shows the percentage of students correctly answering for both compounds according to the three levels of chemical representation. Results indicated that most of the students were able to answer the question at a macroscopic, microscopic and symbolic level for Magnesium Oxide and Sodium Chloride. Most of them were capable of explaining both compounds and their given answers are relatively aligned with the scientific concept. However, the majority of them failed to write an appropriate chemical equation to show the formation of MgO and NaCl. Two mistakes were identified: that they were not able to write a balanced chemical equation and they did not know how to differentiate between chemical equations and chemical formulae. This is relevant to the findings of a study by Hafilah [14] that stated the students' difficulties in applying the chemical equations, chemical formulae and ionic equations when they were asked to explain the formation of a compound.

Furthermore, the higher percentage for the macroscopic level of NaCl compound was due to the capability of students to observe directly the properties of salt. Sodium chloride (NaCl) is known as common salt in our daily lives. This common compound gives students a clear observation of the physical properties of NaCl, where it is a solid and has a white color. By contrast, for the macroscopic level of Magnesium Oxide (MgO), only 46.4% of students could answer the observation question appropriately. In fact, the white ash formed at the end of the experiment was the magnesium oxide. This showed that students have difficulty in relating the chemical changes of the experiment with the macroscopic representation [15, 16]. At the microscopic level, all the students were actually able to explain the formation of both compounds. However, only 53.6% and 50% of students described completely the formation of MgO and NaCl according to the appropriate answer scheme given by an expert chemistry teacher. Instead of explaining the process of donating and receiving electrons for both elements, the better explanation should be to include the electron arrangement of the elements, the dots and cross diagram and the type of bond formed. This was proved by Norimeyati [17], who found that students had problems drawing the formation of a compound using the correct electron arrangement and could not draw the appropriate dots and cross diagram to show the bonding of the compound.

Table 1. Percentages of students correctly answering the question according to the three levels of chemical representation

Type of Questions	Chemical representations	Percentage (MgO)	Percentage (NaCl)
Observation	Macroscopic	46.4%	57.1%
Formation of compound	Microscopic	53.6 %	50 %
Equation involved	Symbolic	32.1%	39.3 %

*N=28 students

Next, the following table presents the percentage of students' skilled to answer the MgO and NaCl compound in the form of macroscopic, macroscopic and symbolic level (see Table 1). Findings showed that total of students who were able to explain both compounds according to the three levels were at a low level, at 14.3% and 21.4% respectively. This supported the findings by Gabel [18], which stated that students have difficulty in understanding chemistry at these three levels and cannot shift easily from one level to another. Hence, helping students to make a connection and see the interactions between the three levels is essential because it is necessary for students to comprehend chemical concepts 19] and it will help students to generate understandable explanations [20]. Consequently, students are successfully developing scientific mental models if they are able to describe the chemical phenomena at each level of representation [11].

Table 1. Percentages of students' able to answer the question according to the three levels of chemical representation

Compound	Chemical representations	N	Percentage
Magnesium Oxide (MgO)	Macroscopic level only	0	0%
	Microscopic level only	10	35.7%
	Symbolic level only	0	0%
	Macroscopic and Microscopic level only	9	32.1%
	Macroscopic and Symbolic level only	0	0%
	Microscopic and Symbolic level only	5	17.9%
	All three levels (Macroscopic, Microscopic and Symbolic Levels)	4	14.3%
	Total	28	100%
Sodium Chloride (NaCl)	Macroscopic level only	0	0%
	Microscopic level only	7	25%
	Symbolic level only	0	0%
	Macroscopic and Microscopic level only	10	35.7%
	Macroscopic and Symbolic level only	0	0%

Microscopic and Symbolic level only	5	17.9%
All three levels (Macroscopic, Microscopic and Symbolic Levels)	6	21.4%
Total	28	100%

4. Conclusion

For a conclusion, the results obtained from the preliminary study concluded that students' have difficulty when describing chemical compound in the three chemical representations which is macroscopic, microscopic and symbolic level. They cannot see the shift or the connection between those particular levels. Finally, they tend to build non scientific mental model in chemical bonding. Thus, present research was important to be conducted in order to help students learn the chemical bonding and furthermore visualize the concepts at the three levels. In addition, the objectives to help students develop their scientific mental model in this topic also become a crucial factor for them to skilled the chemical bonding concepts.

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References

[1] Coll, R.K. The role of models, mental models and analogies in chemistry teaching. In P. Aubusson, A. Harrison and S.M. Ritchie (Eds.). Metaphor and analogy in science education. Dordrecht: Kluwer; 2006.

[2]Justi, R., Gilbert, J. Models and modelling in chemical education. In J. K. Gilbert, O. D. Jong, R. Justy, D. F., Treagust, and J. H. Van Driel (eds.). Chemical education: Towards researchbased practice, 47-68. Dordrecht: Kluwer; 2002.

[3]Nahum T. L., Hofstein A. Mamlok-Naaman R., & Bar-Dov Z. Can final examinations amplify students' misconceptions in chemistry?. Chemistry Education : Research and Practice; 2004. 5(3).

[4]Cittleborough, G. D. The role of teaching model and chemical representations in developing students' mental models of chemical phenomena. Australia: Curtin University of Technology; 2004

[5]Harrison, A. G., Treagust, D. F.Learning about atoms, molecules, and chemical bonds: A case study of multiple-model use in grade 11 chemistry. Science Education; 2000. **84**, p 352-381

[6]Coll, R. K. Chemistry Learners' Preferred Mental Models for Chemical Bonding. Journal of Turkish science Education; 2008.5(1)

[7]Chittleborough, G. D., Treagust, D. F., Mocerino, M. Constraints to the development of first year university chemistry students' mental models of chemical phenomena. Presented at the 11th Annual Teaching and Learning Forum for Western Australian Universities, Edith Cowan University, Australia, February 2002

[8]Bodner, G. M., Domin, D. S. Mental models: The role of representations in problem solving in chemistry. Chemistry Education; 2000, 4(1), p. 24-30.

[9]Johnstone, A.H., Why Science is Difficult to Learn? Things are Seldom What they Seem" Journal of Computer Assisted Learning; 1991, 7, p. 75-83.

[10]Treagust, D. F., Chittleborough, G., Mamiala, T. L., The Role of Submicroscopic and Symbolic Representations in Chemical Explanations. International Journal of Science Education; 2003, 25, p. 1353–1368

[11]Devetak, I. Explaining the latent structure of understanding submicropresentations in science. Unpublished dissertation, University of Ljubljana, Slovenia; 2005.

[12] Jansoon N., Coll R.K., Somsook E. Understanding Mental Models of Dilution in ThaiStudents International Journal of Environmental and Science Education; 2009, 4(2), p. 147-16

[13] Erickson G. L. Children's conceptions of heat and temperature. Science education; 1979, 63(2). P. 221-230

[14] Hafilah O. Kefahaman pelajar tingkatan empat sekolah menengah mengenai ikatan Kimia. Universiti Teknologi Malaysia (UTM) Thesis; 2008

[15] Eilks I., Moellering J., Valanides N. Seventh-grade Students' Understanding of Chemical Reactions: Reflections from an Action Research Interview Study. Eurasia Journal of Mathematics, Science and Technology Education; 2007, 3(4), p. 271-286

[16] Johnson, P. Children's understanding of substances, part 2: Explaining chemical change. International Journal of Science Education; 2002, 24, p. 1037 - 1049.

[17] Noremiyati A. Tahap penguasaan topic ikatan kimia di kalangan pelajar-pelajar sarjana muda sains serta pendidikan (Kimia). Universiti Teknologi Malaysia (UTM) Thesis; 2007.

[18] Gabel, D. L. The complexity of chemistry and its implications for teaching. In Fraser B. J. and Tobin K. G. (Eds.). International handbook of science education, London: Kluwer; 1998,Vol. 1, p. 223–248.

[19] Sirhan G. Learning difficulties in Chemistry: An Overview. Journal of Turkish Science Education;. 2007,4(2)

[20] Farida I., Liliasari, Widyantoro D. H, Sopandi W. Representational Competence's Profile of Pre-Service Chemistry Teachers in Chemical Problem Solving .Paper presented at 4th International Seminar of Science Education, Bandung. 30 October 2010