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INVESTIGATION OF UNIVERSITY CHEMISTRY STUDENTS' MENTAL MODELS OF METALLIC BONDING AND STRUCTURE OF METAL

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ABSTRACT: This study identifies second-year chemistry students' mental models of metallic bonding and structure of metals by using a phenomenographic analysis. Mental models are real representations of objects, ideas or process which individuals generate during the learning process. Sample group consisted of 64 (43 female and 21 male) chemistry students taught all metallic bonding theories. To obtain an in-depth understanding of chemistry students' mental models, the data were collected by using a written instrument with two open-ended questions. They were asked to explain the bonding in the cupper metallic structure by drawing in the first question. In the second question, they were asked to define what the metallic bonding is. The analysis of the data was conducted on two different dates by using the content analysis method by the author. It was concluded that most of the students' mental models were simple, in contrast with the sophisticated complex models taught. Some of the students have also hybrid models of the bonding theories.

Key words: University chemistry students, mental models, metallic bonding

INTRODUCTION

The metallic bonding is one of the central topics in chemistry and involves the use of a variety of models. Students are expected to progress in an understanding of these models easily. In elementary level (6th -8th grades) students are taught a simple particle model of matter (SPM). According to SPM, metal atoms or particles are regarded as the basic structural constituents and particles/atoms are assumed to be spherical are often represented as circles (Cheng and Gilbert, 2014). The sea of electrons metaphor for the metallic bond is used in teaching metallic bonding commonly in secondary education (9th -12th grades). Chemistry students are taught metallic bonding in general chemistry course by using both sea of electrons metaphor again and also the band theory of metals that is a more sophisticated theory.

Research has shown that students have a poor understanding of the bonding in metals and models for metallic structure and bonding at all level (Coll & Taylor, 2002; Coll & Treagust, 2003; Coll, 2008; Taber, 2003). Cheng and Gilbert (2014) indicated that the students were unable to visualize the metal structure in a scientific way. Taber (2003) investigated learners' mental model for metallic bonding in his interview study and characterized learners' conceptualizations of metallic bonding. He found that while some of the students did not think the metallic substance represented would have any bonding, others thought there was some form of interaction in metals, but this was not proper bonding at the beginning of the study. Some of them suggested there would be ionic or covalent bonding in metals or metallic bonds existed between two metals. The "sea of electrons" metaphor for the metallic bond is used in teaching metallic bonding commonly. Taber (2003) found that students seemed to accept the "sea" metaphor uncritically, and to develop images of cations and/or electrons floating, swimming, etc. in the sea without thinking through the consequences of such a model. Other students seemed to develop the "sea" metaphor in relation to ideas about orbital overlap or electrical forces, to provide both a more meaningful framework for interpreting the metallic bond, and a model that is more coherent with developing understanding about other types of bonding (Taber, 2003). One of the problems that led to students' misconceptions about the metallic bonding is that students at both high school and undergraduate level tend to develop hybrid models. Students can use different model together and integrate them which they treat as coherent and finally they can create their own mental models. Besides, representations of scientific models have placed in textbooks or teachers' explanations while teaching models. Sometimes they might be rather confusing. For this reason, to grasp how students visualize the visual representation of metallic structure is important..

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The aim of this study is to identify mental models of the metallic bonding and metallic structure of a group of undergraduate chemistry students after taking general chemistry course and taught metallic bonding theories and models.

METHODS

Research Participants

The participants consisted of 64 (43 female and 21 male) second-year chemistry education students who taught more sophisticated models of metallic bonding in their first academic year as part of general chemistry course.

Data Collection

This is a survey that a written survey enabled to use a sample large enough to reflect the variety of models hold by students. The open-ended response questions were chosen in this study since the metallic bonding can be explained by using a number of different models. Students were asked to provide a drawing of structure and bonding in the copper metal and written explanations of metallic bonding. The drawing task question (1) aimed to probe into their mental visual representations of metallic bonding. In the second question, the main purpose was to obtain students' mental verbal description about metallic bonding.

Data Analysis

This study categorizes the students' descriptions of metallic bonding and bonding in a metallic structure by looking for structurally significant differences that clarify how students describe metallic bonding and draw bonding in the metallic structure. For this reason, analysis of students' answers was based on the phenomenographic method. This method was developed by Marton (1981). He described phenomenography as a "research method for mapping the qualitatively different ways in which people experience, conceptualize, perceive, and understand various aspects of, and phenomena in, the world around them." To determine the reliability of analysis was used intra-judge reliability which would involve a single judge scoring at the same test at two different times (Gay and Airasion, 2000, p.176).

RESULTS and FINDINGS

From the analyses of students' drawings about the metallic structure of cupper asked in question (1), six types of mental models and two hybrid models were identified. The types of mental models obtained from the first question, and students' frequency/percentage are given in Table 1. From Table 1, it was said that a preferable model was *simple particle model* (SPM) that was thought of the elementary grades. Nearly quarter of students (23.4%) drew *simple particle model* (SPM) to show the structure of cupper metal. the Second and third ones were a *unit cell model* (15.6%) and *electron-sea-model* (9.4%), respectively.

Table 1: The frequency and percentage of students' mental model of the structure of metal

Types of Model	f	%
Simple Particle Model	15	23.4
A Unit cell model	10	15.6
Electron-Sea-Model	6	9.4
Covalent bonding/electron cloud model	4	6.3
Models based on Molecular Orbital Theory	4	6.3
Close-packing model	2	3.1
A Unit cell model and Close-packing model together	2	3.1
A hybrid model of a unit cell and particulte models	1	1.6
A hybrid model of covalent bonding model and a unit cell model	1	1.6
$_{29}Cu:1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10}$	4	6.3
No answer/I do not know	15	23.4
TOTAL	64	100.1

In the second questions, students were asked to describe what the metallic bonding was. It was found that nearly 40% of students described metallic bonding as "The bonding which is occurred **among metal atoms** is called as metallic bonding".

CONCLUSION

It was concluded that most of the students' mental models were simple, in contrast with the sophisticated complex models taught. While some of the students thought the metallic bonding as the covalent or ionic bonding, some of the students had hybrid models of the metallic bonding theories used during lessons. Justi and Gilbert (1999) proposed that models constituted of elements of different historical models treated as if they constituted a coherent whole be called as a hybrid model.

It was also found that the metallic bonding was also not seen as a real bonding and students thought that there was some form of interaction in metals as indicated in Taber' study (Taber, 2003). It was found that almost quarter of students still used the Simple Particle Model they brought from elementary school science courses. It can be said that the students' prior knowledge influences how new knowledge is constructed from the data of this study.

RECOMMENDATIONS

First of all, the students should be presented fundamental conditions of the bond occasion in generally taking into account electrostatic attraction and energy. The main problem about difficulties concerning the bonding is that students do not make sense why the atoms come together to occur the chemical bonds. It should be avoided that the simple explanations about bonding such as electron sharing or transferring. While using different models to explain the same topic, why these different models used should be clarified.

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