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SECONDARY STUDENTS' USE OF SUBMOLECULAR REPRESENTATIONS: HOW COMPATABLE THEY ARE WITH THE ACCEPTED MODELS

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Abstract
To analyze students' submicroscopic representations of atoms, molecules and ionic lattice structures a survey design was implemented in the study in which high school Grade 9 Turkish students (n= 100) were participated. The questionnaire included 4 open ended molecular drawing questions that take place in the textbook as molecular models. The data obtained from students' molecular drawings and verbal explanations in the questionnaire were analysed together ideographically. The findings indicated some of the students were able to relate submicroscopic representation with the symbolic ones in an acceptable way. Yet, most of the students failed to show submicroscopic level, instead they used Lewis dot structures with outermost shell electrons for molecular drawings. Most of the students were successful in differentiating between solid, liquid and gaseous state of the same substance at submicroscopic level where the position of the molecules, atoms or ionic lattice were drawn in an acceptable way.
Keywords: submicroscopic representations, secondary school students, molecular models, physical state, chemistry

INTRODUCTION

In order to conceptualize basic terms in chemistry, students need to be able to relate submicroscopic, macroscopic and symbolic levels and make necessary connections between the three levels (Gabel, 2005). As atoms and molecules are invisible entities interacting with each other, it is hard for students to comprehend the microscopic level in chemistry through verbal channels. Thus, models are suggested to be used as they represent many different classes of entities, covering both macro and submicroscopic levels (Gilbert, 2005) However studies indicated that students have difficulties in relating these three levels (Johnstone, 1991).

Taber (2002) stated that learners hold many alternative conceptions in chemistry resulting from the teaching they had received. Despite the fact that molecular models are central idea in chemistry education, 'particle' concept is problematic for students (Johnson, 1998). Students mostly fails in distinguishing between the terms molecule, atom, ion and lattices. Learners had an idea that sodium chloride lattice is comprised of diatomic molecules despite the lattice structure of sodium chloride printed in their textbooks. In recent years, science teaching approaches shifted from traditional teaching practices to constructivist teaching practices in Turkey. Therefore science curricula in high schools have been implemented according to constructivist theory since 2008 (Talim ve Terbiye Kurulu Başkanlığı [TTKB], 2007) and new textbooks were published accordingly. Before switching to constructivist approach the main emphasis in the textbooks was on the macroscopic and mostly symbolic representations of chemistry. On the contrary new textbooks contain molecular models and submicroscopic representations. Thus, this renovation might render the expected outcome concerning the three levels of representations in chemistry. This expectation motivated the present study. In other words, the purpose of this study was to investigate students' representations in chemistry and the reasoning behind their representations.

METHOD

To analyze students' submicroscopic representations of atoms, molecules and ionic lattice structures a questionnaire was designed and implemented in a high school. Grade 9 students (n= 100) participated in the study. The questionnaire included 4 open ended molecular drawing questions. Students were asked to draw sub-molecular level for different states of matter and provide explanations regarding their reasoning behind their representations. Questions were examined by two chemistry instructors who could be accepted as specialist in chemistry education field for validity purposes. Questions were formed related to the concepts occur in the chemistry textbooks as molecular models. In the first question, students were asked to draw $H_2(g)$ and $H_2(l)$ at molecular level. The second question required students to draw NaCl(s) at submicroscobic level. The third question was about drawing HF molecules at submicroscobic level. In the fourth question students were asked to show molecular form of $H_2O(l)$ and $H_2O(s)$. In all four questions students had to explain verbally what they have drawn .

The data obtained from molecular drawings and verbal explanations were analysed together by ideographically. In this analysis, students' drawings were analysed so as to find out not only the modelling they used but also the reasoning behind their modelling. Thereafter, these models were compared with the scientifically accepted ones. Deviations from the scientifically acceptable models were detected and the reasoning behind this deviation was attempted to pinpoint with the help of students' written responses. Also, the molecular models used by the students were compared with those take place in the chemistry textbooks.

FINDINGS

The first question asked students to make a drawing to show $H_2(g)$ and $H_2(l)$ at the molecular level. The results of analysis of students' drawings are presented in Table 1.

Table 1. Students' drawings for the molecular representation of $H_2(g)$ and $H_2(l)$

Students' Drawings	Number of Students (*n* = 100)
Drawing two circles for H atoms linked with a line (3 of them). In liquid state line between atoms is shorter, in gaseous state line between atoms are longer. No difference between molecules in both states.	3
Drawing two circles for H atoms linked with a line (three or four of them). In liquid state line between atoms is shorter, in gaseous state line between atoms are longer. In liquid state molecules are close, in gaseous state molecules are far.	5
Drawing a line to link molecules, liquid state is shorter, gas state is longer, to show gaseous state links are shown in different directions.	2
Drawing a line to link molecules, In liquid state molecules are close, in gaseous state molecules are far.	14
Drawing only one molecule, intermolecular bond is drawn longer in gaseous state and shorter in liquid state	18
Show Lewis dot structure, no difference in liquid and gaseous state	8
Two circles linked together (as shown in the book), gaseous state is further, liquid state closer (drawing many molecules)	26
One circle for $H_{2,}$ drawing many circles, in gaseous state is circles are further; in liquid state they are closer.	21
Gaseous state shown with one circle, liquid state is two circles together, gaseous state is further, liquid state is closer	3

Findings indicated that 26 students could draw the accepted representation for $H_2(g)$ and $H_2(l)$. Some students used a line to link molecules (n=14) and some drew Lewis dot structure (n=8) as molecular drawing. Majority of students could show the difference between liquid state and a solid state. Yet, they differ in their modeling as some changed the length of the chemical bonding (n= 18) whilst some changed the distance between the atoms of H (n= 21). Thus, they failed to distinguish liquid and gaseous states. Another modeling used by students was drawing one circle for molecules of H_2 (n=21) regardless of its state. Or alternatively, some students draw one circle for the gaseous state, two circles for the liquid state (n=3).

The second question required students to draw NaCl lattice structure at submolecular level. The results of students' drawings are presented in Table 2 below.

Table 2. Students' drawings for the molecular representation of NaCl

Students' Drawings	Number of Students (*n* = 100)
Drawing 3 sodium, 3 chlorine circles apart (chlorine atoms are bigger)	2
Drawing one Na and one Cl atoms as circles together	7
Drawing energy levels showing electrons for Na and Cl	14
Drawing Lewis structure showing Na giving one of its electrons to Cl with an arrow	19
Drawing energy levels showing electrons for Na and Cl and linked two energy levels with a line	11
Drawing Lewis structure of both atoms and draw line between the	15

symbols	
Only showed electron configurations	7
Drawing the lattice structure	3
Drawing energy levels of Na and Cl as sharing outermost electrons	6
Drawing energy levels showing electrons for Na and Cl, Na giving one of its electrons to Cl with an arrow	16

According to Table 2, only three of the students were able to draw lattice structure of NaCl in an acceptable way. 19 of the students draw Lewis dot structure showing ionic bonding. Another 15 students also used Lewis dot structure. Yet, they did not attempt to illustrate electron sharing between the two atoms. Some students (n=16) drew energy levels of the two atoms and illustrated one electron shift from Na to Cl with an arrow. Drawings seem to uncover a misconception as 6 students thought that Na and Cl are sharing electrons.

The third question required students to draw HF at submolecular level. Students' drawings were analyzed and its results are given in Table 3. Findings indicated that 21 students could draw the submolecular representation of HF as given in their chemistry textbook. Even thought the scientific modeling illustrated in their textbook, 31 students preferred to draw Lewis dot structure. The rest on the other hand, draw energy levels (n=12) for submicroscopic representation. There seems to be a confusion in some of the students regarding covalent and ionic bonding as 10 students drawn H as giving an electron to F.

Table 3. Students' drawings for the molecular representation of HF

Students' Drawings	Number of Students (n = 100)
Draw a circle for H and a circle for F linked with a line (four or five of them)	16
Draw H and F energy levels sharing an electron as illustrated in their textbook	21
Draw Lewis dot structure H giving an electron to F	10
Draw Lewis dot structure of H and F as sharing an electron	31
Draw energy levels of H and F, H giving an electron to F	10
Draw energy levels of H and F, connected with a line	12

The final question asked students to draw H_2O(l) and H_2O (s) at submolecular level. Students' drawings are presented in Table 4.

Table 4. Students' answers for the molecular representation of H_2O(l) and H_2O(s)

Students' Drawings	Number of Students (n = 100)
Students draw the molecular representation of H_2O as in their chemistry textbook.	34
Draw a circle for O and two circles for H connected with lines.	28

Symbols of H and O connected with lines.	15
Draw Lewis dot structure of H_2O.	12
Draw a circle for O and two circles for H connected linear.	6
Only draw circles.	5

The results of the analysis revealed that 34 students could draw the molecular representation as appears in their chemistry textbook. Another drawing (n= 28) was illustrating O with one circle, H with two and making line between O and two H atoms in an acceptable way. Whilst some students made linear lines between O and H atoms (n= 6). As happens in other questions here again, 12 students draw Lewis dot structure for H_2O. The rest 5 students seems to prefer a simple chemical modeling which is generally used at primary schooling by drawing only small circles for each water molecule. Some students (n=15) appear to have problems not only chemical modeling but also chemical formula as they drew line between symbols of O and H.

DISCUSSION AND CONCLUSION

The present study conducted to investigate whether the renovation in teaching practices have become successful in helping students relate three levels of representations in chemistry. By its nature, constructivist teaching approach which targets conceptual understanding is expected to render students shift between the three levels of representations of chemistry. Yet, this expectation was not realised fully. As some secondary students were able to relate submicroscopic representation with the symbolic ones in an acceptable way, most of the students failed to show submicroscopic level even thought they received the related teaching. Some of the students used or preferred to use Lewis dot structures with outermost shell electrons for molecular drawings instead. This seems to parallel with the existing literature (Canpolat, Pınarbaşı and Sözbilir, 2003). Another finding that is parallel to the literature is confusion between covalent and ionic bonding (Boo, 1998; Öztürk Ürek and Tarhan, 2005; Nicoll, 2001). The findings of the present study indicated that most of the students were successful in differentiating between solid state, liquid state and gaseous state of molecules, atoms and lattice structures. Students seem to struggle to construct the forms of mental model, and need conceptual representations to understand and comprehend the actions of atoms or molecules (Garnett, Oliver and Hackling, 1998). On the whole, research studies concluded that multimedia and multi representational learning environments promote conditions for effective learning (Ainsworth, 1999). The results indicated that teachers in the classroom should facilitate the use multimedia instructional environments emphasizing molecular representations combining macroscopic and symbolic representations.

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