International Online Journal of Educational Sciences, 2012, 4 (3), 563-580

iojes
www.iojes.net

International Online Journal of Educational Sciences

ISSN: 1309-2707

Students' Conceptual Level of Understanding on Chemical Bonding

Aybüke Pabuçcu[1] and Ömer Geban[2]

[1]*Abant Izzet Baysal University, Faculty of Education, Turkey* [2] *Middle East Technical University, Faculty of Education, Turkey*

ARTICLE INFO

Article History:
Received 21.07.2012
Received in revised form 02.12.2012
Accepted 03.12.2012
Available online 15.12.2012

ABSTRACT

The purpose of the study was to investigate the effectiveness of conceptual change oriented instruction on students' conceptual understanding of chemical bonding concepts. Pretest - posttest design of quasi-experimental method was used to determine the effectiveness. Traditionally developed textbook and analogies were utilized in the control group whereas conceptual change texts and Teaching-With-Analogies Model were used in the experiment group. Results revealed that conceptual change oriented instruction caused better understanding, and two modes of instruction developed similar attitude toward chemistry. Science process skill was a strong predictor in understanding, but no effect of gender difference on understanding and on students' attitudes was found. Also, semi-structured interviews were used to examine students' understanding in detail.

Keywords:
Conceptual Change Text, Teaching-With-Analogies Model, Student Generated Analogies, Teacher Generated Analogies, Chemical Bonding Concepts, Misconceptions, Traditional Learning

Introduction

Researchers investigated that students have consistent problems with understanding chemical bonding (Dhindsa & Treagust, 2009; Kind & Kind, 2011) then learning of advanced chemistry content will be a serious problem (Coll & Treagust, 2001; Hilton & Nichols, 2011). Understanding chemical bonding is important to comprehend the nature of the chemical reactions, thermodynamics, molecular structure, chemical equilibrium and some physical properties such as boiling points. Also, reactivity, spectroscopy and organic chemistry concepts cannot be understood unless students understand the chemical bonding theories (Taber & Coll, 2002). In the studies of chemical bonding learning and teaching, many researchers used instruments to assess students' difficulties. For instance, Birk and Kurtz (1999) used the two-tier multiple-choice test to determine the misconceptions about chemical bonding. The results of their study indicated that the common misconception among undergraduate students was that equal sharing of the electron pair occurs in all covalent bonds. Henderleiter, Smart, Anderson, and Elian (2001) used interview to identify how organic chemistry students understood and applied knowledge of hydrogen bonding to the physical behavior of molecules. They asked students to predict and explain how hydrogen bonding influences boiling point and the solubility of molecules. According to findings, some college students did not recognize the necessity for hydrogen to be directly bonded to an electronegative atom for hydrogen bonding occurs, and significant numbers cannot apply their knowledge of hydrogen bonding to physical properties of molecules. In addition, some studies have been made to enhance students' conceptual understanding of chemical bonding (e.g Harrison & Treagust, 2000). Among these, conceptual change approach has a large usage area (e.g Baser & Geban, 2007). The best-known conceptual change model has been that of Posner, Strike, Hewson, & Gertzog (1982). This model holds that learners must become dissatisfied with their existing conceptions as well as find new concepts intelligible, plausible, and fruitful, before conceptual restructuring will occur.

[1] Corresponding author's address: Abant İzzet Baysal Üniversitesi, Eğitim Fakültesi, Bolu, Turkey.
Telephone: +90 3742541000-1629
Fax: +90 374 2534641
e-mail: aybuke@ibu.edu.tr

Conceptual change text is one of the successful conceptual change strategies to facilitate conceptual understanding (Al Khawaldeh & Al Olaimat, 2010; Kenan & Ozmen, 2012). These texts are designed to make readers aware of the inadequacy of their intuitive ideas and help students understand and apply the target scientific concept through the use of explanations and examples (Hynd et.al. , 1994). Many researchers have utilized conceptual change texts because learning from textbooks is an important part of the educational process and these texts can be effectively used in both small and large classrooms to facilitate conceptual change (Chambers & Andre, 1997). Analogies can also play a central role in restructuring of students' conceptual framework because analogy involves an interactive process between what is already known and the new concept presented in instruction (Beall, 1999). Duit (1991) stated that analogies may be valuable tools in conceptual change learning, may facilitate understanding and visualization of abstract concepts and may encourage teachers to take students' prior knowledge into consideration. Moreover, using analogies can facilitate text learning (Glynn & Takahashi, 1998). Iding (1993) found that college students who learned scientific concepts using analogical texts were able to answer significantly more inferential questions compared to those who had received non-analogical texts. Recent interest in the use of analogies in science education has centered on several aspects of analogy including teachers' analogical explanations in the classroom. Thiele and Treagust (1994) found that teachers rarely preplan their analogies and tended to draw upon their own experiences. Mostly teachers have not mention the limitations of analogies in the classroom and this improper use of analogies can lead to undesirable learner effects like misconceptions (Zook & Maier, 1994). Because students have difficulty recognizing the relational and explanatory power of an analogy, they often miss the real point of the analogy, and this is an excellent reason for teachers to use a systematic approach when teaching with analogies. Glynn's (1991) Teaching With Analogy (TWA) Model was one of the several approaches exist for using analogies in teaching and many researchers used this model in the studies. TWA Model includes these 6 steps: (1) Introduce the target concept, (2) Review the analog concept, (3) Identify relevant features of the target and analog, (4) Map similarities, (5) Indicate where the analogy breaks down, and (6) Draw conclusions. Treagust and Harrison (1993) used this model with a Grade 10 optics class on refraction of light. The study indicated that a competent teacher could integrate this systematic approach into a teaching repertoire resulting in student conceptual understanding of the phenomena as expected at this level of science education. One problem with these studies is that they are all cases of teacher-generated analogies. There are few studies of students generating their own analogies. However, there is evidence that analogies are much more effective when they are generated by learners rather than teachers (Pittman, 1999).

Many science education studies have focused on alternative variables that affect students' understanding of science concepts such as science process skills (Pınarbası, 2002), gender differences (Sungur and Tekkaya, 2003), and attitude towards science (George, 2000). Researchers have indicated that science process skill was a strong predictor in understanding the concepts related to science (Preece & Brotherton, 1997). In addition to the cognitive variables, it is now accepted that students' attitude toward science is also very influential in science learning process. Much research in science education suggested that the type of instruction affected students' attitudes toward science as a school subject (Chang, 2002). Moreover, variables external to the classroom such as gender are analyzed to determine their impact on attitudes (Rani, 2000) and on science achievement. In the literature there are contradictory results about gender issue in attitude researches. Dahindsa and Chung (2003) found no significant sex difference in attitudes toward and achievement in science in coeducational schools. However, Barmby et al. (2008) showed that attitudes toward science declined as students progressed through secondary school and this decline was more pronounced for female students. There are also contradictory results about the relationship between gender and understanding chemistry. Some of the researchers concluded that gender difference was affective in understanding chemistry (Chambers & Andre, 1997). However, on the contrary to these findings and supported by this research, some other researchers showed gender difference was not effective (Azizoglu, 2004).

The main purpose of the study is to compare the effects of conceptual change oriented instruction and traditionally designed chemistry instruction on 9th grade students' understanding of chemical bonding concepts and attitudes toward chemistry as a school subject. Conceptual change text was chose to facilitate conceptual change because learning from textbooks is an important part of the educational process. Also, analogies can be valuable tools in conceptual change learning, if they are used with taking into account the key features of teaching with analogies. In this study, Glynn's (1991) TWA model and student generated analogies were used as a part of the conceptual change oriented instruction. Also, in the study to diagnose students' understanding deeply and to minimize each method's disadvantages, interview and two tier multiple-choice test were used together. Furthermore, because science process skills play a significant role in students' science learning, students' science process skills were investigated. Lastly, because of the contradictory results about gender issue in attitude and science education researches, in the study it was examined whether there was a significant difference male and female student with respect to their understanding chemical bonding and their attitudes towards chemistry as a school subject. The key research questions of the study were:

1. Is there a significant difference between the effects of conceptual change oriented instruction and traditionally designed instruction on students' understanding of chemical bonding concepts when their science process skills are controlled as a covariate?

2. Is there a significant difference between males and females in their understanding of chemical bonding concepts, when their science process skills are controlled?

3. Is there a significant difference between students taught through conceptual change oriented instruction and traditionally designed instruction with respect to their attitudes toward chemistry as a school subject?

4. Is there a significant difference between males and females with respect to their attitudes toward chemistry as a school subject?

Methodology

Research Design

In this study, the quasi-experimental design was used. The random assignment of already formed classes to experimental and control groups was employed to examine treatment effect.

Subject

The subjects of the study consisted of 41 ninth grade students (20 boys and 21 girls) from two intact classes of a chemistry course in an urban high school. The age range of the students was about 14-15 years old. Instructional methods were randomly assigned to each class. The data were obtained from 21 students in the experimental and 20 students in the control group.

Instrumentation

Chemical Bonding Concepts Test (CBCT). This test was developed by the researchers to determine students' understanding of chemical bonding. It included 21 items based on the two-tier multiple-choice format. The language of the test was English. The first tier of each item examined the content knowledge with two, three or four alternatives. The second tier consisted of four reasons for the first tier. These reasons include one scientifically acceptable answer supporting the desired content knowledge in the first tier and three misconceptions identified from the literature related to students' misconceptions with respect to chemical bonding (Birk & Kurtz, 1999; Butts & Smith, 1987; Coll & Taylor, 2001; Nicoll, 2001; Tan & Treagust, 1999). A students' answer to an item was considered correct if the students selected both the correct content choice and the correct reason. For the content validity, three chemistry teachers and two chemistry educators examined the appropriateness of the test items in terms of the language, design and accuracy. They reported that the questions were appropriate with chemical bonding content and the grade level of students. The internal consistency reliability of this test was found to be 0.73. This test was given to students in both groups before and after the treatment.

Attitude Scale toward Chemistry (ASTC). This scale was developed by Geban et al. (1994) to measure students' attitudes toward chemistry as a school subject. It consisted of 15 items in 5-point Likert type scale. The reliability was found to be 0.83. ASTC was given to students in both groups before and after the treatment.

Science Process Skill Test (SPST). The test was originally developed by Okey, Wise and Burns (1982) and adapted into Turkish by Geban et al. (1992). It contained 36 four-alternative multiple-choice questions measuring different aspects of science process skills such as identifying variables, identifying and stating hypothesis, operationally defining, designing investigations, graphing and interpreting data. Science process skill test was administered to experimental and control groups in the study to determine the difference between groups concerning science process skills since the variation in achievement may result from the difference in science process skills. The reliability of the test was found to be 0.85.

Interviews with Students. After the posttest, semi-structured interviews were used to examine students' understanding in detail. Four students from the experimental and four students from the control group were randomly selected. The interview schedule was left flexible to allow students to express themselves in relative freedom and to enable the interviewer to ask thought-provoking questions. All of the interviews were audio taped and transcribed verbatim by the researchers.

Treatment. This study was conducted eight weeks. Two ninth grade chemistry classes were selected. One of the classes was assigned as the experimental and the other group was assigned as the control group. Both groups were instructed on the same content of the chemistry course. The language of the instruction was English. The classroom instruction of the groups was three 40-minute sessions per week. The same classroom teacher instructed all classes. The teacher had experience in conceptual change text and analogy instruction. Instruction in both classes was observed by the first author to control for the teacher effect and bias and also to verify the treatment. The teacher bias was not observed during the treatment. The topics related to chemical bonding concept were; the definition and types of bonds (intramolecular and intermolecular), polarity of molecules and electron pair repulsion theory.

Students in the experimental group worked with the conceptual change texts. Prior to the beginning of treatment, teacher mentioned the characteristics of these texts. Conceptual change texts were prepared by the researchers and were written for the following topics (see Appendix A): the definition of a bond, types of bonds, polarity of molecules, and electron pair repulsion theory. Conceptual change texts were constructed by use of Posner et al.'s (1982) conceptual change model. In each of the conceptual change texts, the topics were introduced with questions to make students aware of their naïve conceptions. Some questions in the texts were: Why does chemical bond occur? How two hydrogen atoms are held together? Then, students were informed about probable misconceptions related to the phenomena asked in the question and they were encouraged to discuss these questions. During discussions, mostly students dissatisfied with their existing conceptions, and this situation supported the first condition of Posner et al.'s (1982) model. Then, the teacher directed students to read the paragraph in which the evidence countering the misconceptions and the explanation of the scientific conception was provided. Since chemical bonding is an abstract topic, analogies were also used to explain the concept in the texts. During the presentation of the analogies in the classroom, students were assisted to make relation between basic chemical bonding concepts and analogies. By this way, we contributed to maximum participation of students in the lessons and the students who found incorrect relation between analog and target concepts re-organized their opinions. In the instruction, the step-by-step TWA model was used to teach ionic bond, nonpolar covalent bond and polar covalent bond. For instance, the definition was stated for the polar covalent bond as follows: A polar covalent bond is formed between two different elements in which the bonding pair of electrons is not shared equally. Due to a difference in the electronegativities, the bonding pair of electrons is held closer to the element with the stronger electronegativity. Thus, the element that attracts electrons more strongly acquires a partial negative charge and the other acquires a partial positive charge. Since such a molecule possesses positive and negative poles, such bonds are called polar covalent bonds. This definition was for the first step of TWA (the introduction of the target). After that, a picture, in which man and dog share one string, with explanation was given in the text. This was for explaining the properties of the analogous situation (second step of TWA Model). The explanation of that picture was: Let's look at the following picture. In this picture, man and dog share one string. But they are not equally sharing the string. Man is stronger than the dog so he pulls more strongly than the dog. Then, for the step 3, identifying relevant features of target and analog, teacher explained how the target and analog related. For step 4 of the TWA model, mapping out the similarities between the analog and the target, students discussed the similarities between the analog and the target. For example, one of the similarities was found by student A: Man pulled string more because he is stronger than the dog; and similarly, in polar covalent bond, one atom pulls electrons more than the other because of its higher elecronegativity. After, discussing similarities, students discuss the differences between the analog and the target. This was for the step 5 of TWA, indicating where the analog breaks down. For example, student B pointed out that: Man and the dog are pulling the string by holding two sides. However, atoms are not pulling the electrons by holding. Actually, electrons were attracted by electrostatic force between the nuclei of atoms and the shared electron cloud. For the last step of the TWA, drawing conclusions about the concept, students summarized their findings in the classroom. By using analogies in the conceptual change texts, we accomplished Posner et al.'s (1982) conditions of intelligibility and plausibility because it helps to stress on the students' preconceptions and to make relationship between students' conceptions and scientific knowledge. In our study, experimental group students were also asked to construct their own analogies for covalent bond and ionic bond concepts. Examples from the student-generated analogies were given in Appendix B.

In the control group, teacher explained each concept, asked some questions by directing students' answers and made suggestions when needed. Traditional textbook, included the same topics as the conceptual change texts, were utilized in this group. Whereas the traditional textbook addressed some misconceptions in a rather indirect or abstract way, the conceptual change text addressed misconceptions explicitly. The same analogies applied in the control group were also used in the experimental group to concrete abstract concepts of chemical bonding; however, neither control group students allowed discussing these analogies in the classroom nor did the teacher mention the limitations of the analogies. Moreover, worksheets were given to the control group students as homework. These worksheets contained some practice activities required written responses to reinforce the concepts presented in the classroom.

Results

The analysis showed that there was no significant difference at the beginning of the treatment between groups in terms of students' understanding of chemical bonding ($t=0.53$, $p>0.05$), and students' attitudes toward chemistry as a school subject ($t = 0.77$, $p >0.05$) and their science process skills ($t = 1.72$, $p >0.05$). Science Process Skill Test was administered to all students at the beginning of the study to determine the difference between the groups concerning science process skills since the variation in achievement may result from the difference in science process skills.

Effects of treatment, gender difference and science process skill on understanding of chemical bonding concepts

Groups were compared in understanding by using ANCOVA model. Students' science process skills were taken as a covariate. The results showed that there was a significance difference between the post-test mean scores of the students taught by Conceptual Change Instruction (CCI) (9.35) and those thought by Traditionally Designed Chemistry Instruction (TDCI) (6.29) with respect to understanding of chemical bonding. Also, F value for the Science Process Skill indicated that there was a significant contribution of science process skills on students' understanding of chemical bonding concepts ($F = 12.144$; $p <0.05$). The measures obtained are presented in Table 1.

Table 1. ANCOVA Summary (Understanding)

Source	df	SS	MS	F	P
Science Process Skill	1	53.839	53.839	12.144	0.002
Treatment	1	28.139	28.139	6.347	0.018
Gender	1	7.434	7.434	1.677	0.206
Treatment*Gender	1	45.328	45.328	10.224	0.003
Error	29	128.57	4.433		

When we made a comparison between post-test scores, results supported that increase in the percentage of correct response in the CCI group was higher than that of students in the TDCI group. However, there were still some problematic conceptions even in the experimental group after the treatment especially related to intermolecular forces, structure of NaCl and electrical conductivity of graphite. For example, item 20 was related to Van der Waals Forces. Both groups showed low achievement for this question. After the treatment, whereas 23.5% of the CCI group students answered the two parts of the item correctly, none of the TDCI group students gave correct answer to it. Among the control group, the common misconceptions were that because iodine has more protons, its nuclei pull electrons more strongly than the others, so Cl_2 is gas, Br_2 is liquid, and I_2 is solid at room temperature (41.1%). The percentages of experimental and control group students' selection of alternatives in the posttest are given in Table 2.

Table 2. Percentages of students' selection of alternatives for item 20

Cl, Br and I elements are in 7A group. They found in nature as diatomic and show similar chemical properties. What is the reason that Cl_2 is gas, Br_2 is liquid, and I_2 is solid at room temperature?

(I) Cl-Cl, Br-Br and I-I bonds are all of equal strength.
*(II) Cl_2, Br_2, and I_2 molecules have different numbers of electrons
III) Electronegativity of Chlorine, Bromine and Iodine are different from each other.

Result	Percentage of responses Experiment/Control	
***A)** The attractive forces between the I_2 molecules, which have more electrons among them, are stronger than the others.	52.9	17.6
B) The most electronegative one is Cl. Electronegative atoms are more active so Cl moves faster and it is in gas state	17.6	5.9
C) Because Iodine has more protons, its nuclei pull electrons more strongly than the others.	17.6 5.9 23.5	41.1
D) I-I covalent bond is stronger than the others so I2 is in solid state at room temperature.		

Table 3. Percentages of students' selection of alternatives for item 18

At room temperature, sodium chloride, NaCl, exists as a molecule: (I) True *(II) False

Result	Percentage of responses Experiment/Control	
A) The sodium atom shares a pair of electrons with the chlorine atom to form a simple molecule.	17.6	17.6
B) After donating its valance electron to the chlorine atom, the sodium ion forms a molecule with the chlorine ion.	11.8	41.2
***C)** Sodium chloride exists as a lattice consisting of sodium ions and chloride ions.	52.9 11.8	23.5 11.8
D) Sodium chloride exists as a lattice consisting of covalently bonded sodium and chlorine atoms		

For item 18, the misconceptions that the item measured and the percentages of experimental and control group students' selection of alternatives in the posttest are given at Table 3. As it is seen, the common misconceptions for the item were that the sodium atom shares a pair of electrons with the chlorine atom to form a simple molecule, and sodium chloride exists as a lattice consisting of covalently bonded sodium and chlorine atoms. According to Taber (1994), the misconceptions can be arising from the way ionic bonding is presented in the classroom. Teachers illustrate ionic bonding by drawing the transfer of an electron from a sodium atom to a chlorine atom to from a positive sodium ion and a negative chloride ion. They point to the pair of ions and say that strong electrostatic forces attract the sodium and chlorine ions. Thus the picture of a discrete unit of sodium chloride can be implanted in the minds of the students

Effects of treatment and gender differences on students' attitudes toward chemistry as a school subject

ANOVA was used and results showed that there was no significant difference between post-test scores of the students taught through CCI and TDCI with respect to attitudes toward chemistry as a school subject. Also, it was found that there was no significant difference between post-test mean scores of males and females with respect to attitudes toward chemistry. Table 4 summarizes the result of the analysis. This result can be obtained because of the length of the treatment. The length of the treatment was short; therefore, attitude of students did not change much. Also, there are other factors (educational background, family, school climate) besides teaching method and gender-affecting students' attitude (Papanastasiou & Papanastasiou, 2004).

Table 4. ANOVA summary (Attitude)

Source	df	SS	MS	F	P
Treatment	1	14.761	14.761	0.281	0.600
Gender	1	12.879	12.879	0.245	0.624
Treatment*Gender	1	2.852E-02	2.852E-02	0.001	0.982
Error	30	1574.152	52.472		

Interview results. In this study, interviews were applied to eight students of the 9th grades. Interviews were conducted to examine students' ideas about chemical bonding. Four students from the experimental group and four students from the control group were selected based on achievement after their Chemical Bonding Concepts Test scores. Students from each group were randomly selected who were middle achiever. Students' responses were classified and coded to search for the common themes in their responses. The researcher and a subject-matter expert coded the answers separately, and then the two results were compared. In this research, the percentage agreement (0.90) was used to calculate reliability. Examples of interview questions and students' answers are presented at Appendix C.

In sum, interview results revealed that all students have still some misconceptions after the treatment especially in understanding the structure of NaCl, electrical conductivity of graphite and the differences between the intramolecular and intermolecular forces. However, the number of misconceptions students hold in the TDCI group was higher than that in the CCI group. Some examples for the codes (misconception, Partial Understanding, Sound understanding, No idea) belonging to interview questions are presented below:

Table 5. Codes for students 'response to interview question-1

Most students did not have an accurate chemical bond definition in their mind.

Code	What does the term chemical bond mean to you?	Experiment group	Control group
Misconception	Chemical bond means share electrons or gives or takes the electrons between the atoms.	0	4
Partial Understanding	It forms an image of two or more substances held together by unseen forces. These forces are rather strong and they require energy to be broken	1	0
Misconception	Chemical bonds are the bonds between the atoms. These bonds make the substances solid, liquid or gas related to their strength	3	0

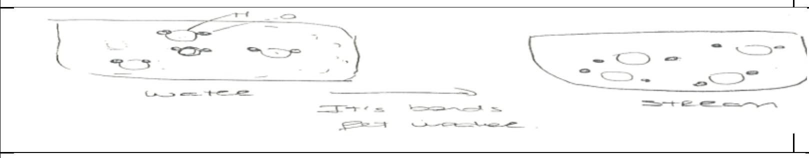
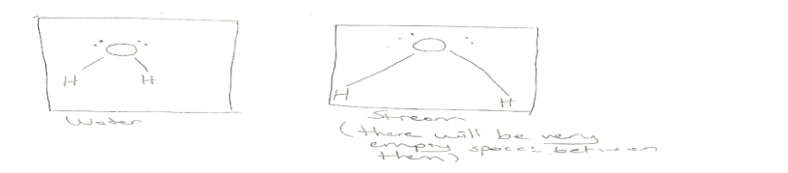
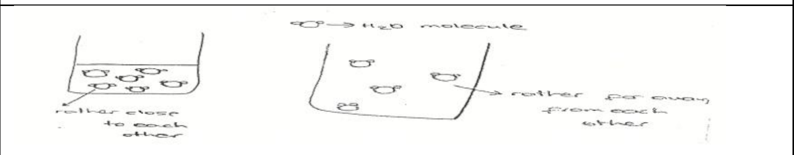
All control group students did not understand the concept of delocalization of electrons in graphite. Half of the students in experimental group could not explain the reason of electrical conductivity of graphite exactly. They wrongly believed that the movement of the layers of atoms in graphite gives rise to its conductivity. This might because they were taught that mobile electrons and ions conduct electricity and therefore the layers of atoms could also electricity because they could move**.**

Table 6. Codes for students 'response to interview question-11

Code	Could you explain why graphite conducts electricity?	Experiment group	Control group
Sound understanding	Graphite has network covalent structure in its bonds. And it also has π bonds, therefore it has freely movable electrons. Because of these electrons it can conduct electricity.	2	0
Misconception	Because graphite has a disordered geometry. It is easer for it to conduct.	0	1
Misconception	It is in network covalent structure so there are layers of carbon. Those layers slide over each other for it to help conduct electricity.	2	1
No idea	I do not know.	0	2

* Students' drawings show that the presence of misconceptions among control group students concerning the particle nature of mater. Most of the students in control group held the misconception that intramolecular covalent bonds (instead of intermolecular bonds) are broken when a substance change phase. And the others thought that bonds do not broken, when substance change its state.

Table 7. Codes for students 'response to interview question-10

Code	Could you please compare the arrangement of the water (H2O) "molecules in water and stream" in a boiling kettle by drawing?	Experiment group	Control group
Misconception		1	3
Misconception		0	1
Sound understanding		3	0

Discussion

As it was stated in the literature, the current study recommends using conceptual change oriented instruction for eliminating students' misconceptions and facilitating conceptual understanding. In the study, conceptual change texts were constructed by use of Posner et al.'s (1982) conceptual change model. This theory holds that learners must become dissatisfied with their existing conceptions as well as find new concepts intelligible, plausible, and fruitful, before conceptual restructuring will occur. So, students in the experimental group were involved in activities that help them revise their prior knowledge and struggle with their misconceptions. In the conceptual change texts, students were asked explicitly to predict what would happen in a situation before being presented with information that demonstrates the inconsistency between common misconceptions and the scientific conceptions. This strategy is to activate students' misconceptions, and then the instructor presented the explanation of the scientific conception, and provides common students' misconceptions followed by evidence countering the misconceptions. As a result, students became persuaded that the scientifically acceptable new conception was more meaningful. Several studies showed that Conceptual Change Textss are effective in creating conceptual change and leading to meaningful learning of many science concepts (e.g. Yilmaz, Tekkaya, and Sungur, 2011).

Analogies are believed to help student learning by providing visualization of abstract concepts and by helping compare similarities of the students' real world with the new concepts. In the current study, analogies were utilized in both groups to help familiarize students with concepts that are abstract. Despite their advantages and usefulness, analogies can cause incorrect or impaired learning depending on the analog-target relationship. For example, if the analog is unfamiliar to the learner, development of systematic understanding is precluded. To be effective, analogies must be familiar to students, and their features must be congruent with those of the target. Since adult perspectives are not identical with those of adolescents, it is not surprising that, even though students are familiar with the physical phenomena or event that might be used as the analogy, they are not always familiar with those features that provide the similarity to the target. The literature suggests that key features of teaching with analogies are to (a) ensure the analogy is familiar to the students (b) map as many shared attributes as possible and (c) identify where the analogy breaks down (Harrison & Treagust, 2006). In the control group, teacher did not mention the unshared attributes between analog and target so that could cause misunderstanding for control group students. Also, control group students could accept the analogical explanation as a statement of reality about the target concept. Therefore analogy use in the control group possibly failed because students did not understand the analog properly. However, in the experiment group to reduce this danger, considerable time was spent by students in discussion of similarities between the analogy and the target. Teacher tried to be sure that students remember the content, not just the analogy. Moreover, in the experimental group, for reliable and valid use of analogies in classroom instruction, teachers presented analogies systematically. In the experimental group, Glynn's (1991) Teaching-With-Analogy model was utilized to increase awareness of students about the limitations of analogies. Lastly, despite use of analogies in control group was centered on teachers' analogical explanations in the classroom, experimental group students were allowed to create their own analogies. Allowing the student to construct analogical relations from their perspective would allow for a deeper understanding of the base and target. In the control group, possibly students' knowledge was not organized the way the teachers think it was. This might cause the difference in the concept tests scores of students in control and experimental group. Niebert, Marsch and Treagust (2012) also stated that not only teaching but also thinking about and understanding science without metaphors and analogies is not possible.

At the end of the study, posttest and interview results were supported each other and they revealed that students have still some misconceptions after the treatment especially in related to structure of NaCl, electrical conductivity of graphite and intermolecular forces. Therefore, teachers must be careful about students' misconception related to these chemical-bonding concepts. Also, CCI did not make significant difference in students' attitudes toward chemistry as a school subject. As Papanastasiou and Papanastasiou (2004) claimed that attitude development is a long process so the duration of the treatment in the study may not be adequate to alter students' attitudes. Moreover, just as in the other studies (e.g Preece & Brotherton, 1997), science process skill was found as a strong predictor in understanding the concepts. There are contradictory results about the relationship between gender and understanding chemistry. Some of the researchers concluded that gender difference was affective in understanding chemistry (Chambers & Andre, 1997). However, on the contrary to these findings and supported by this research, some other researchers showed gender difference was not effective (Azizoglu, 2004). The reason why no significant difference was found in this study might be due to the fact that since the students had similar backgrounds or experience and they are generally familiar with learning subjects from texts or textbook.

Limitations of the Study

1. The subjects of the study were limited to 41 ninth grade students enrolled in a chemistry course in an urban high school. 2. The study was limited to chemical bonding concepts in chemistry. 3. Because of administration procedures, the subjects were not randomly assigned to the groups

Conclusion

Most students had difficulty to understand the chemical bonding concepts. Ausubel (1968) stated that for meaningful learning to occur, new knowledge must be related by the learner to relevant existing concepts in that learner's cognitive structure. That is, according to him, the most important single factor influencing learning is what the learner already knows. In this respect, traditionally designed methods are not so effective in developing conceptual understanding of the subject matter. Because traditionally designed instruction were dependent on teacher exploration without consideration of students' preconceptions. Most of the teaching was focused on the content of the curriculum and on knowledge and information transmission. Instead, CCI are effective to enhance conceptual understanding because students construct their knowledge by making links between their ideas and new concepts through their experience. The current study suggested that conceptual change texts were valuable tools in conceptual change learning; so all textbooks used in the school should be designed according to conceptual change process. Moreover, from many research-studies (Dagher & Cossman, 1992; Niebert, Marsch, &Treagust,2012) it is apparent that science teachers do not use analogies as often as might be expected. This is in spite of the existence of useful analogies in textbooks used in science classrooms (Thiele & Venville, 1993). In addition, research suggests that when analogies are used in class they are frequently not presented in a manner, which enhances their effectiveness. It seems most likely that the vast majority of science teachers have no formal training in the use of analogies and hence it is not surprising that so little use is made of them. Also, Niebert, Marsch, and Treagust (2012) suggested that analogies have to be embodied to be effective in understanding science.They found that instructional analogies that do not lead to the intended understanding of a scientific concept primarily do not refer to a source domain that students understand directly. If conceptual analogy constructed by a teacher are too complex and are even possible to imagine but not embodied by the students, then they often miss their target. In addition to significant amount of researches, the current study advised that teachers should receive in-service instruction about how to implement a teaching model using analogies. For instance, Harrison (1992) observed that when in serviced teachers presented analogies systematically; the resultant student understanding was compatible with scientists' views. Many researchers believed that science teachers call for a carefully planned pedagogy to use analogies effectively. In attempting to address this problem, a number of models or teaching approaches have been produced. The current study supported that the usage of Glynn's (1991) Teaching-With-Analogy) and having students create their own analogies are an effective instructional strategy.

At the end of the study, posttest and interview results revealed that most students have misconceptions about chemical bonding. If these misconceptions are not corrected, they affect further learning negatively. Therefore, teacher must identify students' misconceptions. Teacher can use variety of methods to diagnose misconceptions like interviews and multiple-choice tests. In the study, two tiers multiple choice test were found as much effective as interview to assess students' difficulties. Interviews require too much time to collect and interpret data and also in interviews the numbers of analyzed misconceptions are limited. On the other hand, two-tier tests can be administered to a large number of students and scoring of them is easy. Therefore, teachers can use two-tier tests to diagnose misconceptions more effectively than other instruments.

References

Al Khawaldeh, S.A., & Al Olaimat, A.M. (2010). The contribution of conceptual change texts accompanied by concept mapping to eleventh-grade students understanding of cellular respiration concepts. Journal of Science Education and Technology, 19, 115-125.

Ausubel, D.P. (1968). Educational psychology: A cognitive view. New York: Holt, Rinehart and Winston.

Azizoglu, N. (2004).Conceptual change oriented instruction and students' misconceptions in gases. Unpublished doctoral dissertation, Middle East Technical University, Ankara.

Barmby, P., Kind, P. M., & Jones, K. (2008). Examining changing attitudes in secondary school science. International Journal of Science Education, 30(8), 1075- 1093

Baser, M., & Geban, Ö. (2007).Effectiveness of conceptual change instruction on understanding of heat and temperature concepts.*Research in Science & Technological Education*, *25(1),* 115 – 133.

Beall, H.(1999). The ubiquitous metaphors of chemistry teaching.*Journal of Chemical Education*, *76*, 366-368.

Birk, J.P., & Kurtz, M.J. (1999). Effect of experience on retention and elimination of misconceptions about molecular structure and bonding.*Journal of Chemical Education*, *76(1),* 124-128.

Butts, B., & Smith, R. (1987).HSC chemistry students' understanding of the structure and properties of molecular and ionic compounds.*Research in Science Education*, *17,* 192- 201.

Chambers, S. K., & Andre, T. (1997). Gender, prior knowledge, interest, and experience in electricity and conceptual change text manipulations in learning about direct current.*Journal of Research in Science Teaching*, *34(2),* 107-123.

Chang, C. (2002). Does computer assisted instruction + problem solving = Improved science outcomes? A pioneer study.*Journal of Educational Research, 95 (3*) 143-150.

Coll, R. K., & Taylor, N. (2001). Alternative conceptions of chemical bonding held by upper secondary and tertiary students. *Research in Science and Technological Education*, *19(2),* 171-191.

Coll, R., & Treagust, D. F. (2001). Learners' mental models of chemical bonding.*Research in Science Education*, *31*, 357-382.

Dagher, Z., & Cossman, G. (1992). Verbal explanations given by science teachers: their nature and implications. *Journal of Research in Science Teachinq, 29*, 361-374.

Dahindsa, H.S., & Chung, G. (2003). Attitudes and achievement of Bruneian science students.*Journal of Research in Science Teaching, 25(8)*, 907-922.

Dahindsa, H.S., & Treagust, D.F. (2009). Conceptual understanding of Bruneian tertiary students: Chemical bonding and structure. *Brunei International Journal of Science and Mathematics Education*, *1(1),* 33-51.

Duit, R. (1991). On the role of analogies and metaphors in learning science. Science Education, 75(6), 649–672.

Geban, Ö., Aşkar, P., & Özkan, İ. (1992). Effects of computer simulated experiments and problem solving approaches on high school students. *Journal of Educational Research*, *86*, 5 - 10.

Geban, Ö., Ertepınar, H., Yılmaz, G., Altın, A., & Şahbaz, F. (1994).Bilgisayar destekli eğitimin öğrencilerin fen bilgisi başarılarına ve fen bilgisi ilgilerine etkisi.*I. Ulusal Fen Bilimleri Eğitimi Sempozyumu*: *Bildiri Özetleri Kitabı*, s:1 - 2, 9 Eylül Üniversitesi, İzmir.

George, R. (2000). Measuring change in students' attitudes toward science over time: an application of latent variable growth modeling. *Journal of Science Education and Technology, 9(3*), 213-225.

Glynn, S.M. (1991). Explaining Science Concepts: a Teaching-With-Analogies Model. In S.M. Glynn, R.H. Yeany & B.K. Britton (Eds.), *The Psychology of Learning Science*, 219-239 Hillsdane, NJ, Erlbaum.

Glynn, S. M., & Takahashi, T. (1998). Learning from analogy-enhanced science text. *Journal of Research in Science Teaching*, *35*, 1129-1149.

Harrison, A.G. (1992). *Evaluation of a model for teachinq analogies, in secondary science*. Unpublished Masters thesis, Curtin University of Technology, Perth.

Harrison, A.G., & Treagust, D. F. (2000). Learning about atoms, molecules, and chemical bonds: a case study of multiple model use in grade 11 chemistry. *Science Education*, *84*, 352-381.

Harrison, A.G. & Treagust, D.F. (2006). Teaching and learning with analogies. In P.Aubusson, A. Harrison & S.M. Ritchie (Eds.), Metaphor and analogy in science education (pp. 11–24) Dordrecht, The Netherlands: Springer

Henderleiter, J., Smart, R., Anderson, J., & Elian, O. (2001). How do organic chemistry students understand and apply hydrogen bonding? *Journal of Chemical Education*, *78(8),* 1126-1130.

Hilton A. & Nichols, K. (2011). Representational Classroom Practices that Contribute to Students' Conceptual and Representational Understanding of Chemical Bonding, *International Journal of Science Education*, 33 (16), 2215–2246.

Hynd, C. R., McWhorter, J. Y., Phares, V. L.,& Suttles, C. W. (1994). The role of instructional variables in conceptual change in high school physics topics. *Journal of Research in Science Teaching*, *31(9)*,933-946.

Iding, M.K. (1993). Instructional analogies and elaborations in science text: Effects on recall and transfer performance. *Reading Psychology: An International Quarterly*, *14*, 33-55.

Kenan,O. & Ozmen,H. (2012). Introduction of an enriched computer based teaching material on the particulate nature of matter, *e-Journal of New World Sciences Academy*, 7(1), 1C0491.

Kind, V. & Kind, P.M (2011). Beginning to teach Chemistry: How personal and academic characteristics of pre-service science teachers compare with their understandings of basic chemical ideas. *International Journal of Science Education* 33(15), 2123–2158.

Nicoll, G. (2001). A report of undergraduates' bonding misconceptions. *International Journal of Science Education*, *23(7),* 707-730.

Niebert,K., Marsc, S. & Treagust, D. (2012). Understanding Needs Embodiment: A Theory-Guided Reanalysis of the Role of Metaphors and Analogies in Understanding Science, *Science Education*, Ed 96:849 – 877.

Okey, J.R., Wise, K.C., & Burns, J.C. (1982). *Integrated Process Skill Test-2*. (available from Dr. James R. Okey, Department of Science Education, University of Georgia, Athens, GA, 30602).

Papanastasiou, C. & Papanastasiou, E. C. (2004).Major influences on attitudes toward science.*Educational Research and Evaluation, 10(3*), 239-257.

Pınarbasıȷ, T. (2002). Investigations of effectiveness of conceptual change approach on understanding of solubility concepts. Unpublished doctoral dissertation, Ataturk University, Erzurum.

Pittman, M.K. (1999). Student-generated analogies: Another way of knowing? *Journal of Research in Science Teaching* ,*36* (1), 1-22.

Posner, G.J., Strike, K.A., Hewson, P. W., & Gertzog, W.A. (1982). Accommodation of a scientific conception: Toward theory of conceptual change. *Science Education*, *66(2),* 211-227.

Preece, P. F. W., & Brotherton, P. N. (1997). Teaching science process skills: Long-term effects on science achievement. *International Journal of Science Education, 19,* 895- 901.

Rani, F. (2000).Knowledge attitude and practices of general physicians regarding therapeutic diets. M.Sc. Thesis, Rana Liaqat Ali Khan Government College of Home Economics, University of Karachi.

Sungur, S., & Tekkaya, C. (2003). Students' achievements in human circulatory system unit: The effect of reasoning ability and gender. *Journal of Science Education and Technology, 12(1*), 59-64.

Taber, K. S. (1994). Misunderstanding the ionic bond. *Education in Chemistry*, *31(4),* 100-103.

Taber, K. S., & Coll, R. (2002) Chemical Bonding. In J. K. Gilbert,.et al., (Edit.) *Chemical Education: Research-based Practice*, Dordrecht: Kluwer.

Tan, K. D., & Treagust, D. F. (1999). Evaluating students' understanding of chemical bonding. *School Science Review*, *81(294),* 75-83.

Thiele, R. & Treagust, D. (1994). An interpretive examination of high school chemistry teachers' analogical explanations, *Journal of Research in Science Teaching, 31*, 227-242.

Thiele, R.B., & Venville, G. (1993). *A comparison of analoqies in bioloqy and chemistry textbooks*. A paper presented at the annual meeting of the National Association for Research in Science Teaching, Atlanta.

Treagust, D. F., and Harrison, A. G. (1993). Teaching with analogies: A case study in grade 10 optics. *Journal of Research in Science Teaching, 30*, 1291 – 1307.

Yilmaz,D., Tekkaya, C. & Sungur, S. (2011). The Comparative Effects of Prediction/Discussion-Based Learning Cycle, Conceptual Change Text, and Traditional Instructions on Student Understanding of Genetics, International Journal of Science Education, 33(5), 15, 607–628.

Zook, K.B., & Maier, J.M. (1994). Systematic analysis of variables that contribute to the formation of analogical misconceptions. *Journal of Educational Psychology*, *86*, 589-699.

Appendix A

CONCEPTUAL CHANGE TEXT SAMPLE

WHAT IS THE IONIC BOND?

☹ Most students say that ionic bonds are the transfer of electrons, rather than the attractions of the ions that result from the transfer of electrons. The reason for the transfer of electrons is to achieve a full shell.

These wrong ideas come from the misinterpretation of the definition of the chemical bond.

☺ Ionic bond is the attractive force between oppositely charged ions in an ionic compound.

Analogy for ionic bonding: **Dog - Bone Bonds**
Let's use the natural attraction between dogs and bones as an analogy to the attraction between opposite charges.

Ionic Bonds: One big greedy thief dog! Ionic bonding can be best imagined as one big greedy dog steeling the other dog's bone. If the bone represents the electron that is up for grabs, then when the big dog gains an electron he becomes negatively charged and the little dog that lost the electron becomes positively charged. The two ions (that's where the name ionic comes from) are attracted very strongly to each other.

Let's look at the above analogical model; Of course, this model does not match 100% with real bond formation. However, it makes ionic bonding concept more concrete and interesting.

What are the shared and unshared points of this analogical model with real model?

☺ Example for unshared point: In reality, after ionic bonds are formed, two bonded ions should be stable and happy with this electron transfer. However, in this model, dog that lost its bond does not happy and it does not want to lose its bond and it is an unshared point because it is not match with the scientific fact.

You can also find the other shared and unshared points for this analogy.

…………………………………………………………………...

……………………………………………………………………

Your Analogy for ionic bonding

……………………………………………………………………………………

……………………………………………………………………………………

………………………………………………………………………………

Appendix B

STUDENT GENERATED ANALOGY SAMPLES

Analogy for nonpolar covalent bond: "*Think that your best friend and you go to camp. She forgot to take her blanket but she took her pillow. However, you get your blanket and forgot your pillow. By this way, you share your sleeping bag with her and she shares her pillow with you.*"

Analogy for polar covalent bond: "*Your big brother gets 50 lira a weak for his pocket money, but you get only 30. Your brother's electronegativity is more*"

Analogy for ionic bond: "*Let's say there are two children: Eric and Laura. It's Laura's birthday and Eric gives her present (an electron). Laura becomes negatively charged and Eric became positively charged. They both became stable and happy. At first, Laura was excited because she was curious about the present but now she knows Eric's present so she is stable. At first Eric was excited because he was wondering if Laura would like present, but now he is stable.*

Appendix C

Examples of Interview Questions and Students' Answers

Students' ideas about bonds

Interviewer: "… what are the chemical bonds? What does the term "chemical bond" mean to you?"

Student 1: "Chemical bonds are the bonds between the atoms. These bonds make the substance solid, liquid, or gas related to their strength."

Student 2: " When someone says "chemical bond"...umm. Firstly I think of ionic and covalent bonding.........

Student 5: "It is the bond between or within molecules"

Student 6:"It forms an image of two or more substances held together by unseen forces, in my mind. And, hmm, I get the idea that these forces are rather strong ......and they require energy to be broken."

Interviewer: "… How many bonds do you know?

Student 1: "Um...Three "

Interviewer: "… What are they?

Student 1: "Intermolecular forces for example Van der Waals forces, hydrogen bonds and intramolecular forces such as ionic and covalent

Student 6: "I'm not sure whether intermolecular bonds are chemical bonds, but I think Van der Waals forces, Ionic bonds, covalent bonds, network covalent bonds can be an example for chemical bonds."

Students' responses to the questions revealed that students in both groups do not have an adequate chemical bond definition in their mind. Altough all students do not have enough conceptual knowledge about the types of bonds, only experimental group students noticed the distinction between the intermolecular and intramolecular forces.

Electrical conductivity of graphite

Interviewer: "Could you please explain why graphite conducts electricity?"

Student 1: "I'm not very sure but I'll try to guess. Um. Graphite has pi bonds in addition to the sigma bonds so it is not so stable as diamond. This may be causing the free movement of electrons."

Student 7: "It is in network covalent structure so there are layers of carbon...Maybe those layers slide over each other for it to help conduct electricity."

Student 8:"I don't know. I never thought about that before."

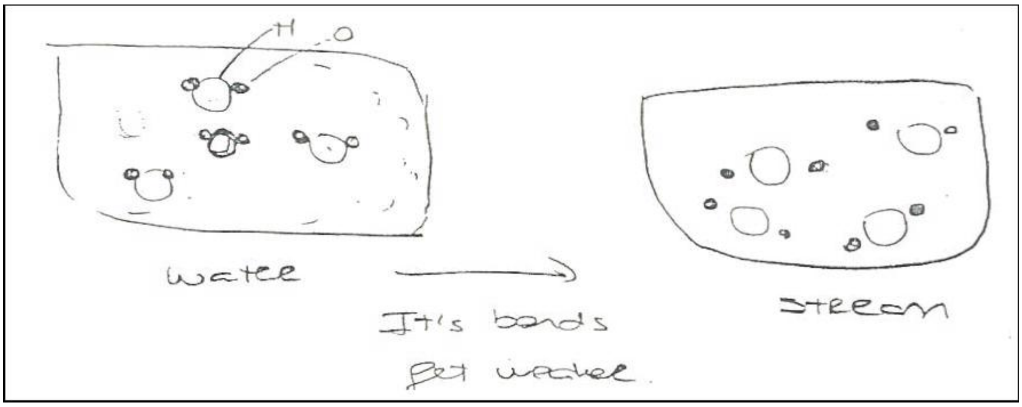
Student 4:"Because of the structure of graphite.....because it has disordered geometry".

These answers showed that students in control group did not understand the concept of delocalization of electrons in graphite. Moreover, half of the students in experimental group could not explain the reason of electrical conductivity of graphite exactly. They believed that the movement of the layers of atoms in graphite gives rise to its conductivity. This might because they were taught that mobile electrons and ions conduct electricity and therefore the layers of atoms could also electricity because they could move.

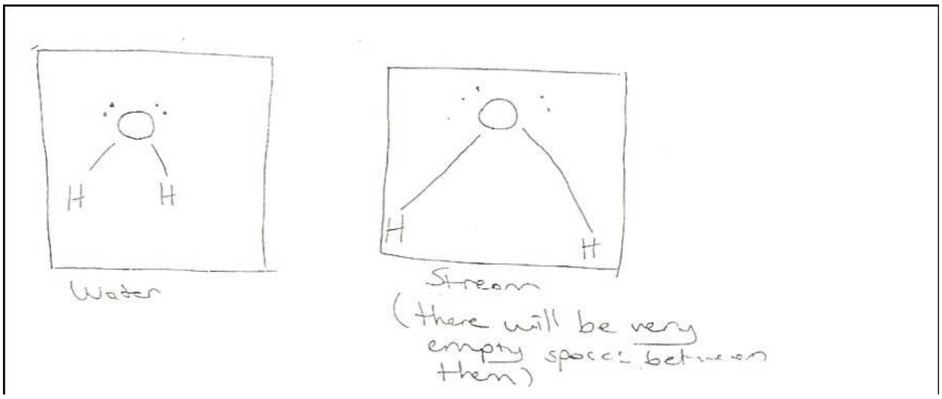
Molecules and Atoms

Interviewer: Could you please compare the arrangement of the water (H_2O) "molecules in water and stream" in a boiling kettle by drawing?

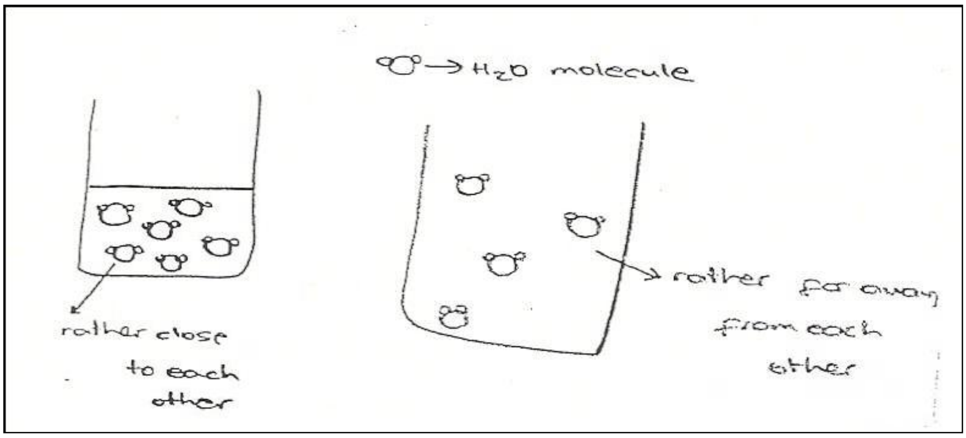
Student 3:



Student 4:



Student 7:

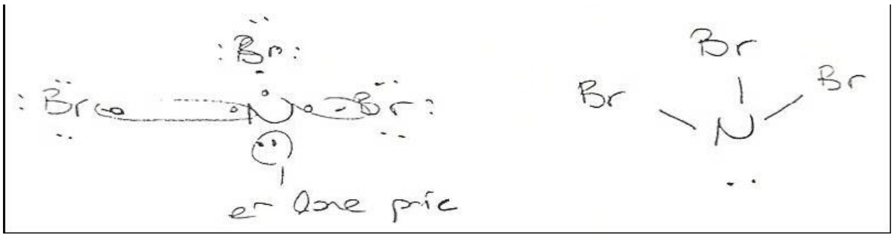


Students' drawings show that the presence of misconceptions among control group students concerning the particle nature of mater. Most of the students in control group held the misconception that intramolecular covalent bonds (instead of intermolecular bonds) are broken when a substance change phase. And the others thought that bonds do not broken, when substance change its state.

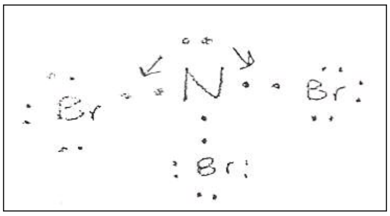
Octet Rule

Interviewer: "Could you please draw the shape of the nitrogen bromine molecule?"

Student 1:



Student 5:



Interviewer: "Why does the nitrogen bromine molecule adopt this geometry?"

Student 1: "Because nitrogen has two nonbonding electrons"

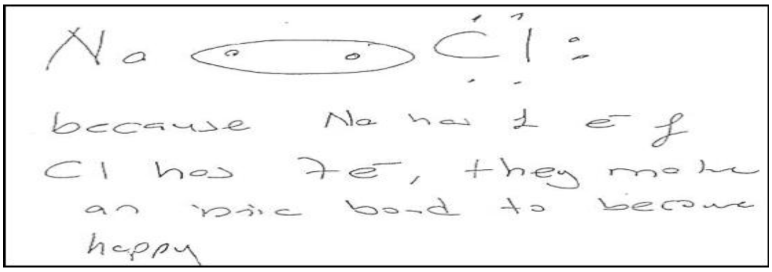
Student 5: "Because the unshared pair of electrons that nitrogen has cause a great deal of negative charges that pushes the three bromine atoms."

All students could correctly predict the shape of the NBr_3. However, 4 control group and 2 experimental group students have misconception in explaining the reason that why it adopt this geometry because they considered that only the nonbonding electron pairs influence the shape of the molecule.

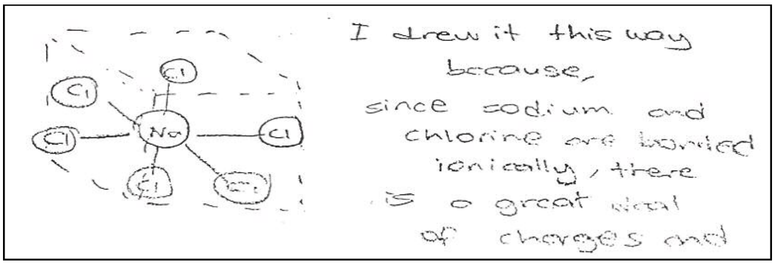
The Structure of NaCl

Interviewer: Could you please draw the structure of sodium chloride (NaCl) and explain why you drew it that way?

Student 1:



Student 8:



In control group, all students believed that the sodium and chloride ions could only from one ionic bond each. Because they only memorized the definition of ionic bond given in the lesson, and they thought that ionic bond formed when atoms donate/accept electron. So it must be electron transfer between the atoms to ionic bonding occurs. However, four experimental group students understand the reason of formation of ionic bond. And they believed that ionic bonds formed between atoms because of the attractive forces. This might because using different instructional strategies to explain this concept.

Intermolecular force

Interviewer: "The boiling point of F_2 is –188 ^oC and the boiling point of Br_2 is 58.8 ^oC. Therefore, Fluorine (F_2) is gas and Bromine (Br_2) is liquid at room temperature. Could you please explain the reason that this huge differences between the boiling points of F_2 and Br_2 molecules?"

Student 2: "Um... because if the atomic number increase boiling point increase...."

Interviewer: "Ok...Why boiling point of molecule is increased with atomic number?"

Student 2: "I have no idea".

Student 4: "It might be result from the different types...but I don't know."

Student 7: "The reason is that the atoms of fluorine and bromine are only held together by London Force. So the one with more electrons has a higher point of boiling, since London Dispersion Forces are based on the movement of electrons (the quantity is important)."

Student 5: "They have both London Forces, but Br_2 has more electrons. Because of this, it has a higher attraction and thus has a higher boiling point."

In this interview, no one in the control group could give correct reason for explaining the differences between the boiling points of given molecules, whereas four students in experimental groups easily could answer it. It might be resulted from using conceptual change approaches in experimental group to teach this subject.