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# THE EFFECT OF CONCEPT CARTOONS EMBEDDED WITHIN CONTEXT-BASED CHEMISTRY: CHEMICAL BONDING

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**Abstract.** *The aim of this study was to investigate the effect of concept cartoons embedded within context-based learning approach on 8th grade students' alternative conceptions of "chemical bonding". Within a nonequivalent pretest-posttest control group design, the study was conducted with 45 8th grade students. To gather data, Chemical Bonding Concept Test (CBCT) with 16 multiple choice questions and clinical interviews with 5 open-ended questions was used to probe their conceptions. Clinical interview questions were prepared in parallel with the same alternative conceptions asked in the CBCT. At the end of the study, context-based approach was found effective at remedying alternative conceptions about chemical bonding. On the other hand, although concept cartoons are found powerful tools to remedy alternative conceptions about chemical bonding, they did not show an extraordinary effect. This suggests that we may need to use more than one intervention method to effectively remedy the alternative conceptions in chemical bonding.*

**Key words:** *alternative conception, chemical bonding, concept cartoons, context-based approach.*

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## Introduction

According to Wright (1979), cartoons can be successful in integrating cognitive domain with the psychomotor domain because they have the power of integrating visual, auditory and kinesthetic learning abilities. Cartoons can be used effectively in teaching because they do not only provide information, they also capture the students' attention; stimulate the active involvement of the students in the learning process (Dalacosta, Kamariotaki-Paparrigopoulou, Palyvos & Spyrellis, 2009). By the recognition of the importance of visual tools in meaningful education, cartoons are also used to promote conceptual learning and concept cartoons are seen as an effective tool. Concept cartoons, which are not designed for humor, present to students the opportunity to interpret and understand concepts (Sexton, 2010). Concept cartoons, which were created firstly in 1991, aimed to elicit learners' ideas and challenge their thinking and improving their understanding (Keogh & Naylor, 1993). As concept cartoons were used in learning environments, it was found that they affected learning positively (Naylor & Keogh, 2013).

While concept cartoons are being used as conceptual change pedagogy, some studies showed that concept cartoons created focused discussions where reasoning behind students' alternative conceptions could have been uncovered with the teachers' provoking questions (Kabapınar, 2005). Dalacosta et al., (2009) used animated concept cartoons and found a significant improvement in the young students' knowledge and understanding of specific science concepts, which were normally difficult to comprehend and often caused misconceptions to them. Concept cartoons enable the presentation of an example of an alternative conception in the class and make students see the topic from a different perspective (Kandil İngeç, 2008).

Naylor and Keogh (2013) implied some other suggestions for classroom use of concept cartoons in addition to conceptual change pedagogy. Concept cartoons may embed scientific ideas in everyday contexts, and the contextual features can influence how the problem is interpreted. In recent years, everyday contexts have been found effective starting points in students' conceptual understanding (Ültay & Ültay, 2014). Thus, context-based approach, focusing on the relevant contexts has begun to be popular. However, context-based approach is principally based on constructivism (Berns & Erickson, 2001; Crawford, 2001; Glynn & Koballa, 2005; Imel, 2000; Lynch & Padilla, 2000). Because constructivism asserted that learning can take place when the students relate scientific knowledge with their pre-existing knowledge, context-based approach suggests using relevant contexts and the context of the real world issue in constructing connections (Kortland, 2010).

Context-based courses do not only make students active, but also offer hope for improving students' engagement in learning chemistry and perceiving the relevance of chemistry (Bennett, Gräsel, Parchmann & Waddington, 2005; King, 2007; Ültay, Durukan & Ültay, 2014). Context-based approach to teach new knowledge exploits relevant contexts that activate student's pre-existing knowledge. Hence, context-based approach creates a "need-to-know" basis to develop coherent mental maps of knowledge and to increase the relevance of the subject (e.g. Ültay, 2013; Ültay & Çalık, 2012; Ültay & Ültay, 2012). Because context-based chemistry makes students more active and shows the relation between the concepts and daily life, context-based chemistry helps students learn the concepts in meaningful contexts (Gilbert, Bulte & Pilot, 2011). Furthermore, students who are afforded the opportunities for applications of the concepts may apply them to make sense of a wider range of tasks (Brook & Driver, 1984).

Barker and Millar (1999, 2000) used context-based approach in chemical reactions, chemical thermodynamics and chemical bonding topics in order to explore students' conceptual learning. They found that students' conceptual learning was improved after the context-based chemistry teaching. In addition, E. Ültay (2012) taught impulse and momentum in physics with context-based approach and he also found similar positive results in favor of the experimental group's conceptual learning. N. Ültay (2012) taught acids and bases in chemistry and examined whether science student teachers' conceptual learning was enhanced. She concluded that context-based approach affected student teachers' motivation positively and this influenced their conceptual learning positively.

In chemistry education, there are some studies that used context-based approach in the periodic table (Bennett et al., 2005; Ramsden, 1997), electrochemistry (Belt, Leisvik, Hyde & Overton, 2005; King, Bellochi & Ritchie, 2008; Markic & Eilks, 2006), water quality (Bulte et al., 2002; King & Ritchie, 2007), chemical bonds (Barker & Millar, 2000; Ekinci, 2010), chemical thermodynamics (Barker & Millar, 2000; Belt et al., 2005), acids and bases (N. Ültay, 2012). But a study which used context-based approach and concept cartoons together is not found in chemical bonding topic. Chemical bonding is a topic that students commonly find abstract and problematic and for which they develop a wide range of alternative conceptions (Coll & Taylor, 2002; Levy Nahum, Mamlok-Naaman, Hofstein & Taber, 2010; Özmen, 2004). Because most chemical bonding concepts are abstract, a student cannot easily understand an atom or interactions between atoms or other elementary particles (Griffiths & Preston, 1999). Chemical bonding theories thus are the cognitive keys that students need to be able to visualize the microscopic world of chemistry (Ünal, Çalık, Ayas & Coll, 2006). It is obvious that chemical bonding is one of the most fundamental topics in chemistry because the concepts in the topic are associated with the molecules' structures, ions, lattices, reactivity, spectroscopy and organic chemistry (Taber & Coll, 2002). In order to comprehend these concepts, students should fully understand the key bonding concepts such as orbital, electronegativity, polarity, and so on. To learn the chemical bonding concepts satisfactorily allow students to make predictions about physical and chemical properties of substances (Levy Nahum et al., 2010). Teichart and Stacy (2002) stated that many studies showed that traditional approach to teaching bonding is problematic and misconceived. An important factor that causes this problematic approach to occur is the textbooks and the way they try to teach (Hurst, 2002).

In the science education, there have been a lot of studies to determine students' understanding, eliminate the problematic approach and alternative conceptions about chemical bonding. For instance, Butts and Smith (1987) found that students were confused about ionic and covalent bonding. Peterson, Treagust and Garnett (1989) and Goh, Khoo and Chia (1993) reported that students believed that intermolecular bonding was stronger than intramolecular bonding. Ekinci (2010) aimed at investigating the effect of context-based teaching method on teaching chemical bonding to 9$^{th}$ grade students. He declared that the experimental group in which the context-based approach was used as a teaching method was found more successful than the control group. Nicoll (2001) tried to determine the alternative conceptions about chemical bonding of undergraduate students in the USA. She used interviews to explore students' knowledge about chemical bonding and she found that most of the students defined chemical bonds as the attractive forces between electrons. Coll and Taylor (2002) aimed at investigating

ISSN 1648–3898

the mental models of learners about chemical bonding and they found that the learners' mental models were simple and realistic, in contrast with the sophisticated and mathematically complex models they were exposed to during instruction.

*The Aim of the Research*

The aim of this study was to investigate the effect of concept cartoons embedded within context-based learning approach on 8th grade students' alternative conceptions of "chemical bonding". Within this aim, the following research questions were explored: (1) Do the concept cartoons embedded within context-based learning approach cause a statistically significant difference in students' "chemical bonding" concepts? (2) How do the students' conceptual understandings of chemical bonding change with the context-based approach?

**Methodology of the Research**

*Research Design and Participants*

The study was carried out within a nonequivalent pretest-posttest control group design and was conducted with 45 8th grade students aged 13-14 from two different classes in a lower secondary school on the north coast of Black Sea Region in Turkey. The groups were randomly assigned as control and experimental groups. The control group consisted of 24 (14 female, 10 male) and the experimental group consisted of 21 (12 female, 9 male) students. The students were coded as E1, E2 …E21 for the experimental group and C1, C2 …C24 for the control group. The classes were taught with a 9-year-experienced science teacher. He voluntarily participated in the study and firstly informed about the context-based approach. Context-based approach was explained and illustrated by the sample materials, and then teaching materials that were prepared for this study were explained by the researcher in detail. This information part of the study lasted 6 hours in 3 weeks. At the end of this period, he was asked to develop a lesson plan for a different topic used in the current study with the context-based approach and he was found he had satisfactory knowledge about context-based approach by three chemistry education experts' common opinion. Interrater reliability coefficient (Cohen's Kappa) between them had been found as 0.90.

Control and experimental group students and the teacher did not perform a similar experience. Students learned chemical bonding concept in the 6th grade for the first time. In the 6th grade, students were taught compounds and the bonds attaching the atoms hold together. They learned the chemical bonding more detailed in the 7th grade. In the 7th grade, students were taught, why atoms made bonds and how covalent and ionic bondings were formed. In the 8th grade, students are expected to learn to determine the types of bonding in several compounds. Therefore, students learned the bonding concept before the 8th grade and they should have been ready to comprehend doublet, octet rules, differentiate covalent and ionic bonding, etc.

*Implementation*

The teacher taught the chemical bonding topic during 8 hours (8*40 min.) with context-based approach in both classes. Concept cartoons were only used in the experimental group. Three separate lesson plans were prepared and used in both classes. The lesson plans were based on context-based approach and "shopping" concept was used as the context. The lessons were carried out with 5E model including enter, explore, explain, elaboration and evaluation steps. The difference between the lesson plans used in the experimental and control groups was only concept cartoons. Each lesson plan included 4 concept cartoons and in total 12 concept cartoons were used. An example concept cartoon is given in Figure 1.

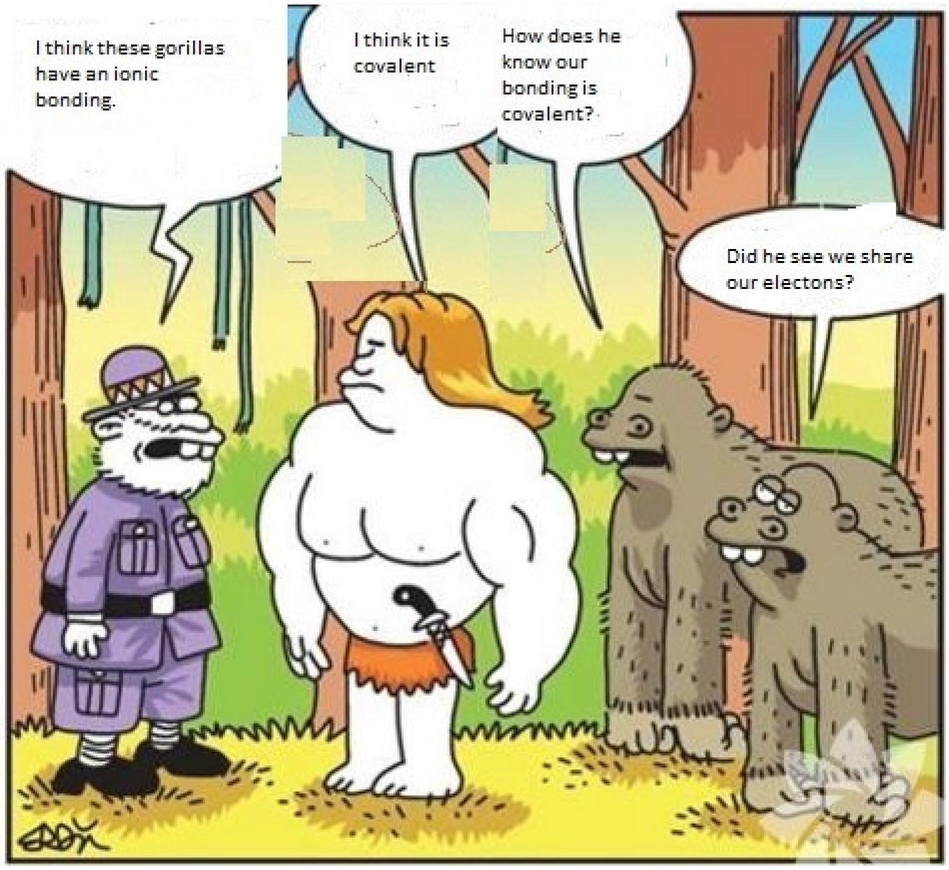



**Figure 1: An example concept cartoon used in the experimental group.**

Concept cartoons were created by the researcher and the figures were taken from internet websites, then the dialogue parts were written by the researcher. After that concept cartoons were examined how they fit with this study by four chemistry education experts.

An example lesson outline is given in Table 1.

**Table 1. An example outline of the teaching design in the experimental group.**

| Step | Lecturer's Role | Students' Role |
|---|---|---|
| Enter | The teacher passed a reading text about shopping which is the context. He asked some curious questions to focus on the topic and relate students' knowledge to the shopping. For example, "How would you associate with the ionic bonding and shopping?" Then the teacher asked "which atoms are prone to accept electrons? And which ones are prone to donor electrons?" After that the first concept cartoon was shown and a few minutes were given to the students to interpret the cartoon. | The students carefully read the text and tried to answer the questions using their pre-existing knowledge.<br>When the concept cartoon was shown, the students firstly read the conversation and then interpreted about the cartoon. |
| Explore | He afforded the students to engage in the activity called "Which element does accept electron?" He helped the students classify the elements as metals, nonmetals and metalloids. He asked questions about the figures students drew about the elements' electronic distribution patterns.<br>After that the second concept cartoon was shown and a few minutes were given to the students to interpret the cartoon. | The students performed the activity called "Which element does accept electron?" In the activity, the students focused on the periodic table and they pointed metals, nonmetals and metalloids. Then the students drew the electron distribution patterns of some elements from the periodic table on the paper. The students tried to explain octet and doublet rules on the figures.<br>When the concept cartoon was shown, the students firstly read the conversation and then interpreted about the cartoon. |

ISSN 1648–3898

| Step | Lecturer's Role | Students' Role |
|---|---|---|
| Explain | He promoted the students to present their knowledge of the electron donation and acceptations and guided them whenever they needed. Then, the teacher explained the topic briefly. After that the third concept cartoon was shown and a few minutes were given to the students to interpret the cartoon. | The students listened to their teachers and asked some questions whenever they had difficulty in understanding his explanation. When the concept cartoon was shown, the students firstly read the conversation and then interpreted about the cartoon. |
| Elaborate | The teacher asked students to show potassium, fluorine, sulfur and magnesium's electronic distribution pattern and asked some questions seeking the relationship between the metal and nonmetal by the tendency to take electron. After that the fourth concept cartoon was shown and a few minutes were given to the students to interpret the cartoon. | The students searched and responded the questions within their small groups and presented their views within a whole-class discussion. When the concept cartoon was shown, the students firstly read the conversation and then interpreted about the cartoon. |
| Evaluate | The teacher afforded the students to engage in the activity called "Let's draw atomic models" to make students see what they learned up to that point. | The students carried out the activity called "Let's draw atomic models". They filled the blanks on the sheet. |

**Note:** *This example outline was implemented in the experimental group as well, but in the control group, only concept cartoons were not used, the rest of the outline was implemented as well.*

*Data Collection Tools*

To gather data, the CBCT with 16 multiple choice questions and clinical interviews with 5 open-ended questions were used. Clinical interviews were carried out by the teacher with 8 students (4 students from each group) and each interview lasted almost 20 minutes. CBCT and clinical interview questions were prepared by considering the same alternative conceptions.

The CBCT administered to probe their conceptions. An example question from the CBCT is given in the following.

| | | |
|---|---|---|
| Question 3: | Teacher: | Can you give an example for the characteristics of ionic bonding? |
| | Hülya: | Compounds having ionic bonding conduct electricity when molten or in solution. |
| | Selim: | Bond involves the electrostatic attraction between oppositely charged ions. |
| | Nevin: | Bond formed between two same nonmetal atoms. |
| | Aykut: | In ionic bonds, the metal loses electrons to become a positively charged cation. |

Which student gave a wrong answer?
Hülya b) Selim c) Nevin* d) Aykut

Clinical interviews with 5 questions were asked to support the data obtained in CBCT. An example question from the interview is given in the following.

Question 2: Can you define 'bond' concept? Why do the compounds form bonds? Please explain.

Distribution of the concepts and the relation of these concepts with concept cartoons according to the question numbers in CBCT are given in Table 2. All concepts are tested with more than one question. Concepts are similar to Nicoll (2001) and Taber (1994)'s concepts which they used in their studies.

**Table 2. Distribution of the concepts and the relation of these concepts with concept cartoons according to the questions in CBCT.**

| Concepts | Questions | Concept cartoons |
|---|---|---|
| Distinguishing between ionic and covalent bonding | 1, 2, 5, 6, 8, 10, 14, 15 | 7th, 9th, 11th and 12th concept cartoons |
| Failing to explain how covalent and ionic bonds are formed | 1, 5, 8, 9, 12, 14, 15 | 8th, 10th, 11th and 12th concept cartoons |
| Failing to consider octet rule | 7, 8, 11, 16 | 1st, 2nd, 3rd and 4th concept cartoons |
| Confusing atoms with molecules | 10, 13 | 3rd, 4th and 6th concept cartoons |
| Failing to explain metallic bonding | 4, 6 | 5th concept cartoon |
| Failing to explain the features of ionic compounds | 3, 6, 12 | 7th and 8th concept cartoons |

In the study, informal observation method was also used via an observation form with the researcher. Observation form contained some field notes about the lessons and the process. In the form, there were the steps of the teaching model and some blank areas for the researcher. The researcher had filled the blanks with her thoughts about the process. Because the lessons were carried out by the teacher, not the researcher, it was worthy to learn how the intervention was going on and to explore the inoperative parts of the intervention. The researcher shared the observation notes with the teacher and they tried to fix missing or inoperative points in subsequent classes. Therefore, observation data analysis was not mentioned in here.

### *Validity and Reliability of Data Collection Tools*

Two chemistry and three science educators for the CBCT, and a chemistry educator, three science educators for the clinical interview questions ensured their appearance, readability and content validity. Also, a few students, apart from the sample under investigation, were asked to read all the instruments and let the author know about any unclear or not understandable points. Afterwards, some minor revisions were made on the items in the instruments. Then, the first version of the CBCT with 20 items was pilot tested with 68 $8^{th}$ grade students, apart from the sample. Item analysis was done and 4 items were found inappropriate because of being weak and very weak and they were omitted from the test. For the last version of the CBCT with 16 items, Spearman-Brown reliability coefficient was found 0.95.

### *Data Analysis*

In the analysis of the CBCT which consisted of multiple choice questions, students get 1 point for the correct answer and 0 points for the wrong answer. Then, the scores of the groups were compared with independent samples t test and paired samples t test in SPSS 16.0.

In the analysis of the clinical interviews, students' answers were put into five categories: sound understanding, partial understanding, partial understanding with specific alternative conception, misunderstanding or specific alternative conception and empty/irrelevant (Abraham, Gryzybowski, Renner & Marek, 1992).

Sound understanding- SU: This category includes students' explanations completely accurate scientifically.

Partial Understanding- PU: This category includes students' explanations which show some part of the correct answer, but do not contain wrong information or alternative conception.

Partial Understanding with Specific Alternative Conception- PUSAC: This category includes partial understanding of scientific explanation with some alternative conceptions.

Misunderstanding or Specific Alternative Conceptions- MU: This category includes students' false explanations which are inconsistent with the scientifically correct answer and these answers can contain some alternative conceptions.

Empty/Irrelevant- E (0 point): This category includes students' irrelevant or not understood answers. Students can leave the question empty.

Interrater reliability coefficient (Cohen's Kappa) between two chemistry and one science educators had been found as 0.87 for the clinical interview.

ISSN 1648–3898

**Results of Research**

The results obtained from the CBCT and clinical interviews are presented in this section.

To answer the first research question which was "Do the concept cartoons embedded within the context-based learning approach cause a statistically significant difference in students' "chemical bonding" concepts?", descriptive results from the CBCT are displayed in Table 3.

**Table 3. Descriptive results of the CBCT.**

| Groups | N | PrT | | PoT | | Percentage change (between PrT and PoT) |
|---|---|---|---|---|---|---|
| | | Mean | Std Deviation | Mean | Std Deviation | |
| Experimental | 21 | 7.48 | 1.91 | 9.95 | 2.25 | 33.02 |
| Control | 24 | 6.88 | 2.11 | 9.04 | 2.51 | 31.39 |

*PrT: Pre test, PoT: Post test*

In Table 3, the experimental and control groups' PrT and PoT scores are presented. PrT scores of both groups are quite close to each other and this provides an advantage to make a comparison between two groups' conceptual learning. In addition, when PoT scores are considered, it is seen that they are also close to each other. When percentage change between PrT and PoT scores is considered, the experimental group could have increased their PrT scores more than the control group.

Normal distribution is checked with One-sample Kolmogorov Smirnov test in order to use parametric tests in the analysis of the data, and test distribution is found normal. Then, independent samples t test is done to check either equality of variances or identify the significant difference between the groups' PrT and PoT scores. Data obtained from the analysis is given in Table 4.

**Table 4. Independent samples t test results for PrT and PoT of the groups.**

| | | Levene's Test for Equality of Variances | | | | | |
|---|---|---|---|---|---|---|---|
| | | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference |
| PrT | Equal variances assumed | 0.009 | 0.926 | 0.995 | 43 | 0.325 | 0.601 |
| | Equal variances not assumed | | | 1.002 | 42.939 | 0.322 | 0.601 |
| PoT | Equal variances assumed | 0.001 | 0.971 | 1.274 | 43 | 0.209 | 0.910 |
| | Equal variances not assumed | | | 1.284 | 42.972 | 0.206 | 0.910 |

According to Table 4, after equality of variances is provided by Levene's Test, it is seen that there is no significant difference between the groups' PrT and PoT scores. Paired samples t test is performed to determine the groups' learned the topic significantly for the second research question and the data is shown in Table 5.

**Table 5. Paired samples t test results for the experimental and control groups' PrT and PoT.**

| Groups | Tests | t | df | Sig. (2-tailed) |
|---|---|---|---|---|
| Experimental | PrT-PoT | -9,080 | 20 | 0.00 |
| Control | PrT-PoT | -4,194 | 23 | 0.00 |

According to Table 5, there is significant difference between the PrT and PoT scores of the groups. It means that both groups effectively learned chemical bonding. Table 6 summarizes the percentages of alternative conceptions in PrT and PoT of the CBCT.

**Table 6. Percentages of the students' alternative conceptions in the PrT and PoT of the CBCT.**

| Alternative Conception | Experimental | | CC | Control | | CC |
|---|---|---|---|---|---|---|
| | PrT | PoT | | PrT | PoT | |
| Distinguishing between ionic and covalent bonding | 47.61 | 40.47 | +7.14 | 48.95 | 42.70 | +6.25 |
| Failing to explain how covalent and ionic bonds are formed | 59.18 | 47.61 | +11.57 | 64.28 | 52.97 | +11.31 |
| Failing to consider octet rule | 73.80 | 34.52 | +39.28 | 59.38 | 27.08 | +32.30 |
| Confusing atoms with molecules | 54.76 | 30.95 | +23.81 | 66.66 | 54.16 | +12.5 |
| Failing to explain metallic bonding | 35.71 | 26.19 | +9.52 | 33.33 | 41.66 | -8.33 |
| Failing to explain the features of ionic compounds | 38.09 | 36.50 | +1.59 | 48.61 | 40.27 | +8.34 |

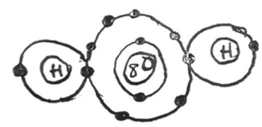
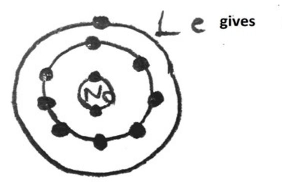
According to Table 6, experimental and control group students' conceptual learning is improved after the implementation. For instance, "distinguishing between ionic and covalent bonding", "failing to explain how covalent and ionic bonds are formed ", "failing to consider octet rule", "confusing atoms with molecules" and "failing to explain the features of ionic compounds" alternative conceptions' percentages are decreased in PoT for both groups. However, the percentage of decreasing in the experimental group is found more than in the control group. Even though, the statistical analysis does not imply a significant difference between PoT results, Table 6 shows that the experimental group is better in eliminating alternative conceptions. The only alternative conception whose percentage is increased in the control group is "failing to explain metallic bonding".

Table 7 shows sample student quotations obtained from the clinical interviews about chemical bonding.

**Table 7. Sample student quotations obtained from the clinical interview in regard to the conceptual understanding levels.**

| Question | CUL | Students | | Frequency | | Sample Student Quotations |
|---|---|---|---|---|---|---|
| | | Exp. | Cont. | Exp. | Cont. | |
| 1. What are the octet and the doublet rules? How can you associate octet and doublet rules with bonding? Please explain. | PU | E1, E11, E14, E18 | C9, C14, C21 | 4 | 3 | According to the doublet rule, an atom should complete the outer shell to 2 electrons, and in the octet rule, the atom should complete the outer shell to 8 electrons. (E1, E11, E14, E18, C9, C14, C21) |
| | E | - | C3 | - | 1 | |
| 2. What is bonding? Why do atoms bond? Please explain. | SU | E14 | C9 | 1 | 1 | Bond is an attraction between atoms that allows the formation of chemical substances that contain two or more atoms. (E14, C9)<br>The bond is caused by the electrostatic force. (E1, E11, C21)<br>Atoms make bonds to be more stable. (E18) |
| | PU | E1, E11 | C21 | 2 | 1 | |
| | PUSAC | E18 | - | 1 | - | |
| | E | - | C3, C14 | - | 2 | |
| 3. How do chemical bonds (ionic and covalent) form? | SU | E1, E11, E14, E18 | C21 | 4 | 1 | Ionic bonding involves the electrostatic attraction between oppositely charged ions. Covalent bonds are formed between nonmetal atoms with electron sharing. (E1, E11, E14, E18, C21)<br>Ionic and covalent bonds are formed with electron exchange. (C9) |
| | PUSAC | - | C9 | - | 1 | |
| | E | - | C3, C14 | - | 2 | |

ISSN 1648–3898

| Question | CUL | Students | | Frequency | | Sample Student Quotations |
|---|---|---|---|---|---|---|
| | | Exp. | Cont. | Exp. | Cont. | |
| 4. Can you explain the bonds formed between NaCl and H2O atoms by drawing? | PU | E1, E14 | C21 | 2 | 1 |  Oxygen needs two electrons to make a bond and two hydrogen atoms give two electrons. (E1)   Na gives one electron and makes a bond with Cl. (C9) |
| | PUSAC | - | C9 | - | 1 | |
| | E | E11, E18 | C3, C14 | 1 | 2 | |
| 5. What are the characteristics of ionic and covalent bond? Could you give examples of daily life? | SU | E1, E14 | C21 | 2 | 1 | Ionic compounds are electrically conductive. Covalent bonds are formed between nonmetal atoms with electron sharing. NaCl can be an example for ionic compounds and H2O for covalent bonding. (E1, E14, C21) |
| | PU | E11 | C9 | 1 | 1 | |
| | E | E18 | C3, C14 | 1 | 2 | |

*CUL: Conceptual understanding level, SU: Sound understanding, PU: Partial understanding, PUSAC: Partial understanding with specific alternative conception, MU: Misunderstanding or specific alternative conceptions, E: Empty or irrelevant answer*

According to Table 7, it is seen that the students in the experimental group gave answers in sound understanding and partial understanding categories more than in the control group. It means the experimental group students understood the chemical bonding concepts more than the control group.

**Discussion**

As can be seen in Table 5, it can be said that context-based approach in the experimental and control groups has positive effects on conceptual understanding of chemical bonding. The reason of this situation may be the daily life examples and activities used in both groups. At the same time, using concept cartoons in a context did not provide superiority for the experimental group statistically.

According to Table 6, it is seen that both groups remedied alternative conceptions after the implementation, except one alternative conception ("Failing to explain metallic bonding"). The percentage of this alternative conception is increased and this case can be explained that sometimes teachers can cause some alternative conceptions' formation (Çalık, 2003; N. Ültay, 2012).

It is more beneficial and informative to discuss Table 6 and 7 together because data are discussed to support each other. In Table 6, it was seen that students cannot have distinguished between ionic and covalent bonding. Some students conceptualized the sodium and chlorine atoms as being held together by covalent bonds (Butts & Smith, 1987). Some students used electron sharing when explaining ionic bonding instead of electrostatic attraction (Birk & Kurtz, 1999). The reason of this case can be explained with the way ionic bonding is presented (Taber, 1994). Tan and Treagust (1999) explained that teachers illustrated ionic bonding by drawing the transfer of an electron from a sodium atom to a chlorine atom to form a positive sodium ion and a negative chloride ion. Then teachers pointed to the pair of ions and the electrostatic forces between ions. Thus, students learned this picture firstly and it was implanted in the students' minds. In the same way, in the third question in Table 7, one student explained chemical bonds formation with only electron exchange in ionic bonds. Because of the same reason probably, students confused some of the concepts used in chemical bonding such as atom, molecule and ion (see Table 6). Chemical bonding is a topic that includes relations between other chemistry topics and it requires prerequisite knowledge of some fundamental chemistry concepts such as atom, molecule, ion, etc. If students could not have learned these concepts, it will be quite difficult to comprehend chemical bonding. According to Taber (1997), students explicitly use the notion of ion-pairs as molecules, and this case prevents students from learning ionic bonding.

Students failed to explain the features of ionic compounds. After the implementation, in the experimental group very little change in a positive way was seen. Although, the control group was considered as more learned, the PoT percentage showed that both groups did not show a considerable progress (see Table 6). Taber (1995) claimed that learners invoke intramolecular bonding in ionic compounds. Additionally, there is some evidence that learners appreciated the relationship between intermolecular bonding and physical properties such as boiling point (Peterson & Treagust, 1989; Peterson et al., 1989; Taber, 1998). Students also failed to show their knowledge about metallic bonding. Because students try to classify substances into only two groups as having ionic and co-valent bonding, so they have difficulty in understanding metallic bonding (Taber, 1998). In the same way, students stated that the bond between two metallic atoms (for example $Li_2$) is basically covalent bonding instead of metallic bonding in most studies (Levy Nahum, Mamlok-Naaman, Hofstein & Krajcik, 2007).

According to Levy Nahum et al. (2007), the teaching of bonding is often too simplistic in many chemistry textbooks and the main problem arises from this point. The common approach used by curriculum developers is to show the substances in four different categories, the ionic, molecular, covalent and metallic lattice and discuss each of these structures. These chemical bond types (ionic, covalent, and metallic bonds) are often discussed as very different entities, and the polarity concept is introduced only as a property associated with covalent bonds (Hurst, 2002). Thus, it prevents students from constructing the concepts in a scientifically accurate way; students fail to establish the relation polarity and chemical bonding. Another problematic issue about the chemistry textbooks is that some textbooks used in developing countries teach the chemical bonding by Bohr atomic model (Mirzalar Kabapınar, 2008). In Table 7, this case can be seen from the students' drawings of chemical bonds in $H_2O$ and NaCl. Using Bohr atomic model in teaching chemical bonding in secondary school affected negatively students' modern atomic theory in future.

Another alternative conception is about octet and doublet rules appeared in students' minds. In Table 6, the experimental and control group students are found successful in eliminating it, while the experimental group is slightly better. As seen in Table 7, all students in the experimental group could have explained the octet and the doublet rules. In the control group, only one student could not have explained the first question in the interview. But students could not have associated satisfactorily octet and doublet rules with bonding in the interview. Taber (1998) argues that students could use octet rule to explain chemical bonding because they can see bond types as a dichotomy, believe in ionic molecules and consider "proper bonds" rather than difference in magnitude. When the students are asked to explain why the bonds are formed in the second question of the interview, they state that bonds are formed to be more stable. When the results obtained from the CBCT are considered (see Table 6), a similar result, the experimental group slightly better than the control group, can be seen. Because concept cartoons are based on everyday situations that do not appear to be scientific, so the students lacking in confidence are less likely to be intimidated by the science and more likely to engage with them (Naylor & Keogh, 2013). Although students in both groups eliminated this alternative conception up to a good level, it is not eliminated completely. Because there are also other alternative conceptions in students' minds and they are always in interaction with each other, it is quite hard to eliminate alternative conception which is resistible to change (Guzzetti, 1997). In addition, alternative conceptions can exist in two forms: soft-core and hard-core alternative conceptions. Hard-core alternative conceptions are quite resistant to change with one intervention (Lakatos, 1970).

When Table 6 and 7 are considered as a whole, it is seen that the experimental group is performed better than the control group. There are some reasons for the experimental group being better. (1) *Guiding student affect to the course*: This study supports findings from other studies that visual imagery, as used in the concept cartoons, can be an engaging and useful way of guiding student affect to the course (Alerby, 2003; Kinchin, 2004; Sexton, 2010). In the study, when the students saw the concept cartoons, they relaxed and focused on the funny things which were not about the course but they were, in fact. (2) *Effective stimulus for argumentation*. Concept cartoons acted as an effective stimulus for argumentation because they enable argumentation to take place without the need for any formal structure, specific vocabulary, or teacher intervention in managing the process of argumentation (Naylor & Keogh, 2013). After the concept cartoons were shown to the students, they were given some time to interpret about the cartoon with the peers, then they shared their feelings and thoughts about the cartoons by considering the topic which will be taught. (3) *Informal learning setting*. Concept cartoons could have bridged

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the gap between formal and informal learning settings because they were based around everyday situations that appear to involve ordinary characters doing ordinary things. (4) *Motivation and engagement*. Concept cartoons are found highly motivating for all ages and for learners having behavioral and emotional disabilities. In this study, some students, who were called as disinterested in the course, were surprised and liked the cartoons. For these students, engaging on the course was very difficult, but the concept cartoons highly motivated them and made them be interested in the course.

**Conclusions and Recommendations**

The research findings reported here suggest that all groups showed some progress at remedying alternative conceptions about chemical bonding. This case can be explained with the context-based approach which was found successful at conceptual learning in the literature. It is found that using relevant contexts could help students to remedy alternative conceptions in chemical bonding. Context-based approach effectively helped students to relate the content knowledge and the context which was related to the daily life.

It can be said that concept cartoons are found good tools to remedy alternative conceptions about chemical bonding; however, concept cartoons still did not show an extraordinary or amazing effect. Thus, it can be seen that the intervention has not completely remedied the alternative conceptions used in the CBCT as suggested in other studies in the literature. This can be fixed with using more than one intervention model to effectively remedy the alternative conceptions in chemical bonding, because each conceptual change method and the combination of them result in conceptual change being stored in the students' long term memory.

In conclusion, concept cartoons embedded within context-based approach were found effective at remedying chemical bonding alternative conceptions. But, in order to get a more positive result, a combination of conceptual change methods can be used. Because it is important to deal with students' alternative conceptions for further topics' understanding, teachers should present more plausible concepts than the students' existing ones by creating necessary conditions with conceptual change methods.

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